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Transactions of American Society for Steel Treating

Vol. V April, 1924 No. 4

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Weldless Rings for Gears forged from Agathon Alloy Steel by The Mitchell Steel Company, Cincinnati, Ohio

Below: Drawing down a weldless ring in Mitchell Steel Company plant

Why Forgemen and Machinists Prefer Agathon Alloy Steels

FORGEMEN like to forge Agathon Alloy Steels because of their soundness, freedom from blowholes, pipes, segregations and surface defects.

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AGATHON ALLOY STEELS

TRANSACTIONS

of the

American Society for Steel Treating

Vol. V April, 1924 No. 4

PLANS FOR SPRING SECTIONAL MEETING WELL UNDER WAY

THE plans for the spring sectional meeting of the American Society for Steel Treating to be held under the auspices of the Tri City chapter of the society on May 22 and 23 at Moline, Ill., are well under way. The headquarters for this meeting will be at the new LeClaire hotel.

The executive committee consisting of H. B. Bornstein, chairman of the Tri City chapter, C. H. Burgston, R. Henry, H. O. Koehler, C. A. Schoessel, C. H. Lage, J. F. Lardner, C. U. Scott, H. Brown and A. H. Putnam, have been working hard to make this sectional meeting the best that will have been held by the society. As reported in the March issue of TRANSACTIONS, Chairman Bornstein has appointed the following committees, all of which report much progress in their plans. The committees are: PUBLICITY COMMITTEE: C. H. Lage, J. F. Lardner and R. Henry; FELLOWSHIP COMMITTEE: C. U. Scott; BANQUET COMMITTEE: H. Brown and H. O. Koehler; PAPERS AND PROGRAM COMMITTEE: C. H. Burgston; AUTOMOBILE AND PLANT VISITATION COMMITTEE: A. H. Putnam and REGISTRATION COMMITTEE: C. A. Schoessel.

While all of the details of this meeting have not been completed, the following is a brief review of what has been planned.

THURSDAY, MAY 22

Following registration on Thursday morning, May 22, there will be a technical session, followed by a luncheon. A second technical session will be held in the afternoon. Papers will be presented by Dr. Anson Hayes, Iowa State college, Ames, Iowa;

C. B. Swander, metallurgist, Wagner Electric Co., St. Louis; R. G. Guthrie, metallurgist with the Peoples Gas Light and Coke Co., Chicago, and J. H. Nelson, metallurgist, Wyman-Gordon Co., Worcester, Mass.

In the evening, a banquet will be held jointly with the Tri City Manufacturers' association and the Tri City Engineers' club

LeCLAIRE HOTEL
Moline, Illinois

at which time our president, Dr. George K. Burgess and several notable speakers will be guests of the societies.

Friday, May 23

On Friday, May 23, plans have been arranged for plant visitation both in the morning and afternoon. Plenty of automobiles will be available for the transportation of the visitors to the various manufacturing plants and points of interest.

For those who are golf fans, the committee has made arrangements for a golf tournament to be held over the Rock Island Arsenal golf course on Friday morning. Trophies have been arranged for and much interest has been shown by many of our members who plan on attending this meeting.

The Rock Island Arsenal golf course is reported to be one of the finest courses in the Middle West and this tournament planned by the committee should be a very successful affair. Do not fail to bring along your golf clubs.

The LeClaire hotel which will be headquarters for this meeting is a modern hotel having been completed about a year ago. It has very comfortable rooms having private baths, both tub and shower and at rates of $2.50 to $3.00 and $3.50 per day for single person. There are plenty of rooms at $2.50. The hotel provides very suitable accommodations for technical meetings and the fullest co-operation of both the hotel management and the Moline chamber of commerce has been promised.

In co-operation with the plans of the Tri City chapter, the Rockford chapter of the society are eliminating their regular May meeting at Rockford in order that their efforts may be directed toward helping to make the spring sectional meeting an unqualified success. The members of the Rockford chapter are planning to attend this meeting en masse, going to Moline by automobile. The roads to Moline are reported to be in excellent condition, being paved all the way from Milwaukee, South Bend, Chicago and St. Louis. The fact that the roads are in such good condition will undoubtedly result in many of our members driving through to the meeting.

FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING FOR THE YEAR 1923

THE official report of Nau, Rusk & Sweringen, certified public accountants, covering the results of their audit of the books of the society is submitted herewith.

This statement again shows a very healthy condition of our finances, the Society working within its income and making substantial increases to its reserves and surplus.

The "Income and Expense Statement" shows an increase of about 30 per cent over our 1922 turnover which indicates a considerable increase in the society activities.

By action of the board of directors the sum of $10,000 was added to the permanent convention reserve fund, from the profits of our 1923 convention, to further insure the Society in case of a financially unsuccessful convention. The principal of this fund has been invested in United States government bonds.

Full details of the audited report are herewith given. The official copy of this report is on file at the society offices and is open for the inspection of any interested members.

EXHIBIT A

BALANCE SHEET

AMERICAN SOCIETY FOR STEEL TREATING

December 31, 1923

ASSETS				
CASH				
The Cleveland Trust Co.:				
(Commercial Account)			$ 3,886.18	
(Savings Account)			2,714.67	
The Equity Savings & Loan Co. (Savings Account)			8,868.53	
The Union Trust Co. (Savings Account)			1,082.42	
Petty Cash			25.00	$16,576.80
INVESTMENTS				
Euclid Village, Ohio 6% Water Bonds			3,000.00	
U. S. Treasury Certificates			2,015.00	
U. S. Liberty Bonds			18,000.00	23,015.00
ACCOUNTS RECEIVABLE				
Advertising—Schedule No. 1		$2,166.24		
Pittsburgh 1923 Convention—Schedule No. 2		1,219.22		
Sundry Accounts—Schedule No. 3		1,234.05	4,619.51	
Less—Reserve for Doubtful Accounts			1,000.00	3,619.51
INVENTORY—Transactions, Bindery Stock and Howe Medal				2,119.48
FURNITURE AND FIXTURES (Book Value)				1,000.00
PREPAID				
1924 Convention Expense			436.16	
Rochester Sectional Meeting			54.35	490.51 46,821.30
LIABILITIES, RESERVES AND SURPLUS				
Accounts Payable				1,149.27
Reserve for Dues Paid in Advance				10,000.00
Permanent Convention Reserve				20,000.00
H. M. Howe Medal Fund				3,000.00
Surplus (Balance 1-1-23 $7,997.44—Addition for Year $4,674.59)				12,672.03 $46,821.30

CERTIFICATE

We have made an audit of the books and accounts of the AMERICAN SOCIETY FOR STEEL TREATING for the year ended December 31, 1923 and in our opinion, the above Balance Sheet—Exhibit A, together with the annexed Income and Expense Statement—Exhibit B, correctly presents its financial status at December 31, 1923 and a history of its financial transactions for the year then ended, basing the income from dues upon cash receipts and other income upon accruals.

Respectfully submitted,
NAU, RUSK and SWERINGEN.
Certified Public Accountants

EXHIBIT B

INCOME AND EXPENSE STATEMENT

AMERICAN SOCIETY FOR STEEL TREATING

Year ended December 31, 1923

INCOME		
Advertising		$23,704.60
Membership Dues		30,598.03
Pittsburgh 1923 Convention		38,990.98
Transactions Sales		1,164.45
Bindery Sales		484.25
Reprint Sales		746.45

Pins and Button Sales	49.00	
Pencil Sales	52.75	
Discount on Purchases	105.12	
Interest Earned	1,270.75	
Interest on Howe Medal Fund	72.95	
Miscellaneous Income	108.36	
Write-up Value of Bonds purchased at a Discount	222.80	$97,570.49
EXPENSES		
Returned to Local Chapters		12,751.45
Bindery		108.35
Reprint		484.15
Pencils		51.00
Transactions		
Paper and Cover Stock	2,693.37	
Printing	8,595.80	
Cuts	1,711.67	
Postage	502.39	
Editor's Salary	3,500.00	
Editorial Assistance	40.00	
do Traveling Expense	266.91	
Clerical	1,442.41	
Advertising Commissions	371.70	
Rent	662.25	
Stationery	153.00	
Office Supplies	124.09	
Executive Salary	1,625.00	
Mailing and Miscellaneous Expense	243.03	21,931.62
Secretary's Office		
Executive Salary	2,600.00	
Rent	1,163.10	
Clerical	1,893.02	
Traveling	945.59	
Stationery	388.95	
Office Supplies	209.96	
Postage	853.74	
Telephone and Telegraph	374.62	
Auditing	175.00	
Miscellaneous Expense	500.42	9,104.40
President's Office		
Traveling Expense		134.11
Treasurer's Office		
Bookkeeper's Salary	1,112.78	
Rent	138.00	
Auditing	225.00	
Miscellaneous	179.35	1,655.13
Pittsburgh Convention		
Convention Expense—General	25,732.49	
Executive Salary	2,275.00	28,007.49
Directors' Expense		
Traveling	1,891.40	
Miscellaneous	180.70	2,072.10
National Committee		
Traveling	590.30	
Miscellaneous	932.18	1,522.48
Sectional Meetings		
Chicago	398.39	
Lehigh Valley	377.60	775.99
Increase of Membership		322.25
Data Sheets		927.63
Library		257.28
Uncollectible Accounts		349.15
Howe Medal Expense		574.37
Discount Allowed		60.37
Bank Exchange		5.38
Incidentals		44.29
Reduction in Value of Furniture and Fixtures		1,756.96
Balance Disposed of as follows—		
Addition to Reserve for Permanent Conventions	10,000 00	
Addition to Surplus	4,674.59	$14.674.59
		$97,570.49

EFFECT OF TEMPERATURE ON THE IMPACT RESISTANCE OF LOW CARBON STEEL DEFORMED AT DIFFERENT TEMPERATURES

By Nicholas Richardson and E. K. MacNutt

Abstract

The material used in these tests was commercial steel plate 0.18 to 0.19 per cent carbon. The steel as received, being too brittle, was annealed at 700 degrees Fahr. Annealed strips cut from the plate were cooled or heated to 20 different temperatures, and deformed at these temperatures by pressing in a 105-degree V-die and again flattening. Twenty similar strips were deformed as above at the "blue brittle" temperature, 570 degrees Fahr. Charpy impact test specimens were machined from the strips, care being taken to cut the notch in a manner that would allow the most deformed part of the material to be in the rupture section of the test specimen.

Test specimens were cut from the original annealed plate for comparison of effect of temperature on the impact resistance of the material in the nondeformed state. All tests were made on the Charpy impact testing machine.

It was found that material of this type deformed at temperature from—58 to 700 degrees Fahr., when tested at normal atmospheric temperatures, has about 7 to 14 per cent of the impact resistance shown by the annealed nondeformed material.

Material deformed at 570 degrees Fahr. "blue brittle" temperature has a lower impact value when tested at temperatures between—58 to 700 degrees Fahr. than nondeformed material. The effect of deformation at temperatures from—58 to 700 degrees Fahr. in reducing the impact value at atmospheric temperatures, increases as the temperature of deformation increases. Deformation at "blue brittle" range reduces impact value at temperatures—80 to 700 degrees Fahr. from 32 to 94.5 per cent in comparison with similar tests on nondeformed material.

Introduction

THE object of this investigation was to determine the effect on the resistance to impact, at normal atmospheric temperature,

A paper presented by title at the fifth annual convention of the Society held in Pittsburgh, October 8 to 12, 1923. The authors are members of the Watertown Arsenal metallurgical staff, Watertown, Mass.

of steel plate which had been worked or deformed at different temperatures. (Experiment I). Also the determination of the effect of different temperatures on the resistance to impact of similar materials which had previously been worked or deformed at approximately 570 degrees Fahr., or in the so-called "blue brittle" temperature zone (Experiment II), as well as the effect of temperature on impact resistance of the same materials, in the nondeformed annealed condition.

Material

The material used in these experiments was cut from a piece of shear mill plate 5/8 inch thick. The chemical analysis of this stock showed it to have the following composition:

C.	Mn.	Si.	S.	P.	Ni.	Cr.
.19	.54	.015	.064	.013	Nil.	.02

The plate was sawed up into strips 6 3/4 x 2 3/16 inches and marked as shown in Fig. 1. Strips 21 to 43 inclusive were used in Experiment I, and strips 1 to 20 inclusive, were used in

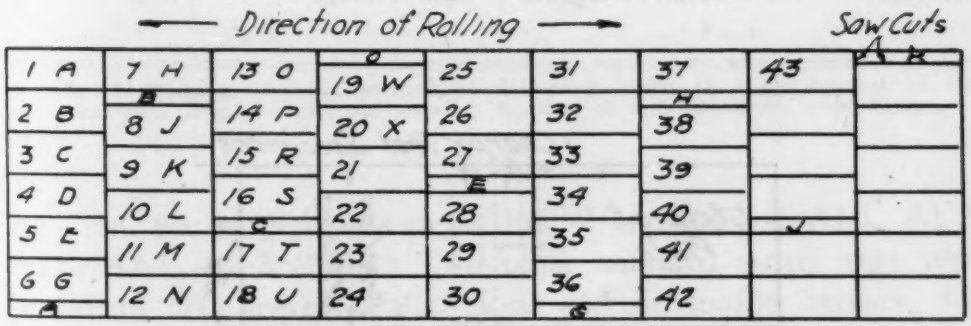


Fig. 1—Diagram showing method of cutting strips from shear plate in Experiments 1 and 2. Shear plate 5/8-inch thick was sawed into strips 2¾ x 6¾ inches and ¾ x 6¾ inches. Strips 21 to 43 were used in Experiment 1, and strips 1 to 20 in Experiment 2. Narrow strips A through K were used in the uniformity tests.

Experiment II. Nine narrow strips, marked A, B, C, D, E, G, H, J and K were cut out at the same time and used to establish the degree of uniformity to be expected of this material.

Table I shows the results, the average foot-pounds absorbed being 8.37 for the material in the condition "as received," the mean divergence from this average was 14 per cent. The degree of uniformity of the material can thus be judged. It is believed that the divergencies are due to uneven cooling of the plate after rolling.

Experimental

A preliminary experiment was carried out to determine the degree of decrease in resistance to Charpy impact to be expected when a plate steel of similar carbon content was deformed in

Table I

Charpy Impact Values for Material as Received

Marks	Ft.-Lbs.	Fracture	Remarks	% divergencies from Average	Brinell No. (500 K. G.)
			Not broken		
A	7.19	Fine Crystalline	Rode on pendulum	—14.3	91
B	8.30	Fine Crystalline	Rode on pendulum	— 1.0	92
C	10.36	Fine Crystalline	Rode on pendulum	+23.4	92
D	6.65	Fine Crystalline	Rode on pendulum	—20.7	107
E	8.76	Fine Crystalline	Rode on pendulum	+ 4.4	91
G	8.30	Fine Crystalline	Rode on pendulum	—1.0	94
H	10.02	Fine Crystalline	Rode on pendulum	+19.7	88
J	9.66	Fine Crystalline	Rode on pendulum	+15.1	92
K	6.11	Fine Crystalline	Rode on pendulum	—27.1	100
Average:	8.37	Mean divergence	from Average	—14.%	

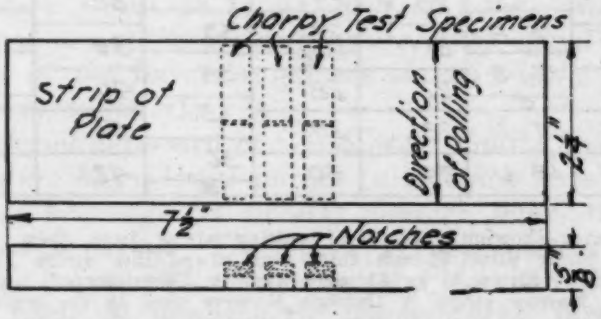


Fig. 2—Diagram showing location of test bars in preliminary experiments.

the "blue brittle" temperature zone, as compared with the impact resistance of that steel in the annealed and unworked condition, and also to develop experimental methods. When in the natural condition, it was found that this material could not be bent at atmospheric temperature, to give a sufficient deformation, without fracturing. In consequence all test material was annealed.

The material used was commercial structural 5/8 inch

thick of the following composition, which is similar to the composition of the material used in the experiments:

C.	Mn.	Si.	S.	P.	Ni.	Cr.
.18	.57	.020	.047	.009	Nil.	.02

Strips 7½ x 2½ x 5/8 inches were cut, and annealed at 1700 degrees Fahr., held one-half hour and cooled in furnace. Small Charpy impact test specimens were then cut from two of the annealed strips in the nondeformed condition, the specimens being

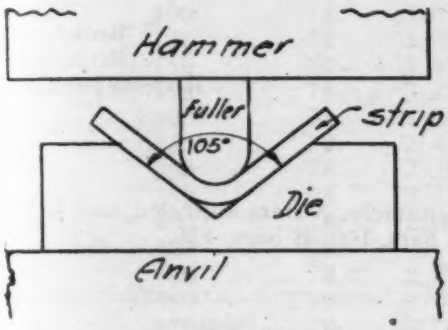


Fig. 3

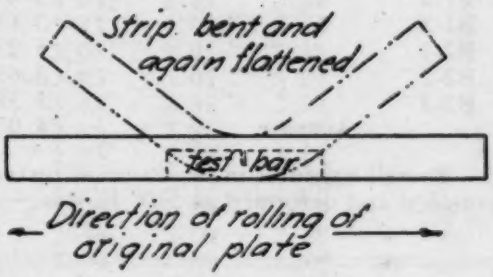


Fig. 4

Fig. 3—Diagram showing method of deforming strips in V-die by use of the steam hammer. Fig. 4—Diagram showing location of test specimens and notches, in strips.

cut from the strip as shown in Fig. 2 and marked A1-1, A1-2, A1-3, A2-1, A2-2, A2-3. Two other annealed strips were then heated to 570 degrees Fahr. in an electric muffle furnace, for use in the bending and flattening tests.

The temperature of the strips was estimated by comparison with a similar dummy strip in which a hole had been drilled to allow for the insertion of a thermocouple. The dummy strip and the experimental strips were placed in the furnace, and when the temperature of the interior of the dummy strip was 570 degrees Fahr. as shown by the thermocouple, the temperature of the experimental strips was considered to be the same. The deformation or working, was accomplished by quickly pressing the strip into a 105 degree V-die by pressure from a steam hammer. After bending to 105 degrees, the strip was again placed in the furnace, brought up to 570 degrees Fahr. and flattened under pressure from

Table II

Charpy Impact Values for Annealed and Deformed Material

Mark	Condition of Material	Ft.-Lbs.	Fracture	Remarks
A1-1	Annealed, not deformed	20.77	Crystalline center with silky edge	Did not break, rode on pendulum
A1-2	"	28.30	"	"
A1-3	"	26.50	"	"
A2-1	"	23.44	"	"
A2-2	"	31.37	"	"
A2-3	"	27.25	"	"
	Average	26.27		
B1-1	Annealed, bent 105° and flattened at nominal 570°F.	3.25	Crystalline	Did not break, rode on pendulum
B1-2	"	3.05		Broke
B1-3	"	3.65		Broke
B2-1	"	5.27		Rode on pendulum
B2-2	"	3.65		"
B2-3	"	5.58		"
	Average	4.07		

Brinell hardness in condition as tested, namely, A Bars annealed, and B bars annealed and deformed at 570° F. was:—A bars, 100; B bars, 126.

Table III

Temperatures at which Strips were Deformed

Strips Marked	Temperature at which strip was bent and flattened. Degrees Fahr.	Marks on Charpy bars from deformed strip	Remarks
21	— 80		Strip broke
22	— 58	22-1, 22-2, 22-3	
23	— 43	23-1, 23-2, 23-3	
43	0	43-1, 43-2, 43-3	
24	30	24-1, 24-2, 24-3	
25	50	25-1, 25-2, 25-3	
26	100	26-1, 26-2, 26-3	
27	125	27-1, 27-2, 27-3	
28	150	28-1, 28-2, 28-3	
29	175	29-1, 29-2, 29-3	
30	200	30-1, 30-2, 30-3	
31	250	31-1, 31-2, 31-3	
32	300	32-1, 32-2, 32-3	
33	350	33-1, 33-2, 33-3	
34	400	34-1, 34-2, 34-3	
35	450	35-2, 35-3	
36	500	36-1, 36-2, 36-3	
37	550	37-1, 37-2, 37-3	
38	570 (Blue Brittle)	38-1, 38-2, 38-3	
40	600	40-1, 40-2, 40-3	
41	700	41-1, 41-2, 41-3	

Table IV

Charpy Impact Values and Temperatures of Deformation Tests were made at 78 degrees Fahr.

Strip Marked	Temperature of Deformation Degrees Fahr.	Temp. of Test Degrees	Charpy specimens from each strip 1 ft.-lbs.	2 ft.-lbs.	3 ft.-lbs.	Aver. Ft.-Lbs.	Remarks
22	— 58	78	3.45	3.35	3.55	3.45	
23	— 43	78	3.25	3.95	*(5.27)	3.60	*Result discarded.
43	0	78	3.85	3.95	3.25	3.68	
24	30	78	3.25	3.35	3.35	3.31	
25	50	78	3.45	2.95	3.15	3.18	
26	100	78	3.05	3.25	2.75	3.01	
27	125	78	3.05	4.04	2.85	3.31	
28	150	78	3.45	3.25	4.04	3.58	
29	175	78	3.25	3.05	3.05	3.11	
30	200	78	2.95	3.05	3.05	3.01	
31	250	78	2.47	3.45	2.85	2.92	
32	300	78	2.56	3.65	2.95	3.05	
33	350	78	2.37	2.95	2.56	2.62	
34	400	78	2.09	2.56	2.27	2.30	
35	450	78	....	2.09	2.09	2.09	
36	500	78	2.27	2.56	2.09	2.30	
37	550	78	1.61	2.09	1.99	1.89	
38	570B.B.	78	2.09	2.09	1.99	2.05	
40	600	78	2.09	2.47	1.99	2.18	
41	700	78	2.09	2.09	2.09	2.09	

the steam hammer, Fig. 3. The accurate temperature at which deformation took place was not directly determined. Experiments in another investigation, however, had shown that the drop in temperature resulting from the transfer of the strip from the furnace to the bending die, did not exceed two degrees Fahr. It is, therefore, believed that in the experiments herein described, that the temperatures recorded are within two degrees Fahr. of the actual temperature, and are termed "nominal" temperatures.

Charpy impact test specimens were then machined from the deformed and again flattened strip as shown in Fig. 4. The impact tests were made on a small Charpy impact testing machine having the following constants:

Capacity.....216.5 foot-pounds.
Weight of pendulum.....50 pounds.
Speed of impact.....16.68 feet per second

The test specimens had the dimensions as shown in Fig. 5.

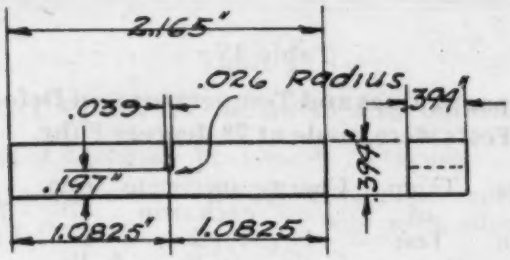


Fig. 5—Sketch showing Charpy type impact test specimen.

Fig. 6—Impact values obtained on material deformed at 20 different temperatures and tested at 78 degrees Fahr.

Table V

Charpy Impact Values for Specimens Deformed at 570 degrees Fahr. Using Twenty Different Testing Temperatures

Strip Marked	Temperature of Deformation Degrees Fahr.	Temp. of Test Degrees Fahr.	Charpy specimens from each strip 1 Ft.-lbs.	2 Ft.-lbs.	3 Ft.-lbs.	Aver. Ft.-lbs.	Remarks
1A	570	—80	1.16	1.16	1.16	1.16	
2B	570	—40	1.61	1.34	1.34	1.43	
3C	570	0	1.52	1.70	1.61	1.61	
4D	570	32	2.09	1.80	1.80	1.89	
5E	570	50	0.97	0.97	1.16	1.03	
6G	570	100	1.16	2.09	2.09	1.78	
7H	570	125	1.52	2.09	2.09	1.90	
8J	570	150	2.85	3.15	2.37	2.79	
9K	570	175	3.25	4.04	3.25	3.51	
10L	570	200	6.11	4.44	4.95	5.16	
11M	570	250	11.19	23.58	12.98	15.91	
12N	570	300	17.80	25.03	26.50	23.11	
13O	570	350	.....	19.00	20.10	19.55	Average of Two
14P	570	400	22.86	25.76	22.16	23.59	
15R	570	450	21.19	24.30	20.77	22.08	
16S	570	500	22.30	22.30	22.30	22.30	
17T	570	550	26.35	28.60	24.88	26.61	
18U	570	570	23.30	24.30	25.76	24.45	
19W	570	600	17.41	18.74	16.76	17.63	
20X	570	700	18.87	22.16	....	20.51	Average of Two

Table VI

Charpy Impact Values on Specimens at Twenty Different Temperatures
Material Non-Deformed

Mark	Temp. of Test Deg. Fahr.	Specimen 1 Ft-lbs.	Specimen 2 Ft-lbs.	Aver. Ft-lbs.	Fracture and Remarks
BA	— 58	1.43	0.88	1.15	Rather coarse crystalline, no draw.
BB	— 43	0.79	0.79	0.79	Finer crystalline, no draw.
BC	0	2.95	2.47	2.71	Rather coarse crystalline, no draw.
BD	30	2.95	2.95	2.95	Rode on pendulum but broke, rather coarse crystalline.
BE	50	2.76	3.65	3.20	Rather finer, rode on pendulum, did not break.
BG	100	25.18	29.52	27.35	Rode on pendulum, did not break.
BH	125	35.96	33.25	34.60	Rode on pendulum, did not break.
BJ	150	35.80	35.80	35.80	Rode on pendulum, did not break.
BK	175	42.37	43.72	43.04	Rode on pendulum becoming fibrous.
BL	200	42.37	42.20	42.28	Rode on pendulum becoming fibrous.
BM	250	46.28	45.77	46.02	Rode on pendulum, fibrous.
BN	300	37.42	40.86	39.14	Rode on pendulum, fibrous.
BO	350	39.38	38.55	38.96	Rode on pendulum, fibrous.
BP	400	39.05	38.22	38.63	Rode on pendulum, fibrous.
BR	450	45.60	39.71	42.65	Rode on pendulum, fibrous.
BS	500	33.88	45.94	39.91	Rode on pendulum, fibrous.
BT	550	43.22	49.23	46.22	Rode on pendulum, fibrous.
BU	570	49.23	44.91	47.07	Rode on pendulum, fibrous.
BW	600	42.20	40.70	41.45	Rode on pendulum, fibrous.
BX	700	31.21	29.52	30.36	Rode on pendulum, fibrous.

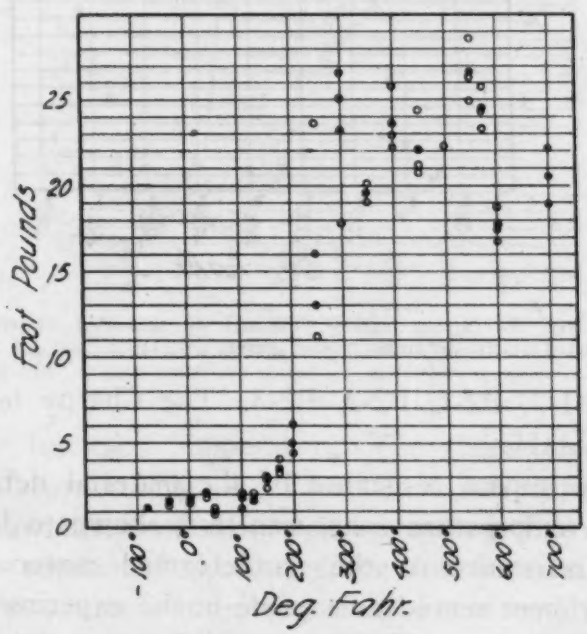


Fig. 7—Impact values obtained on material deformed at 570 degrees Fahr. and tested at 20 different temperatures.

Care was taken to cut the notches as shown, thereby insuring that the material which had suffered the greatest deformation was in the section of the test specimen which resisted the impact stresses. The annealed and deformed test specimens were marked

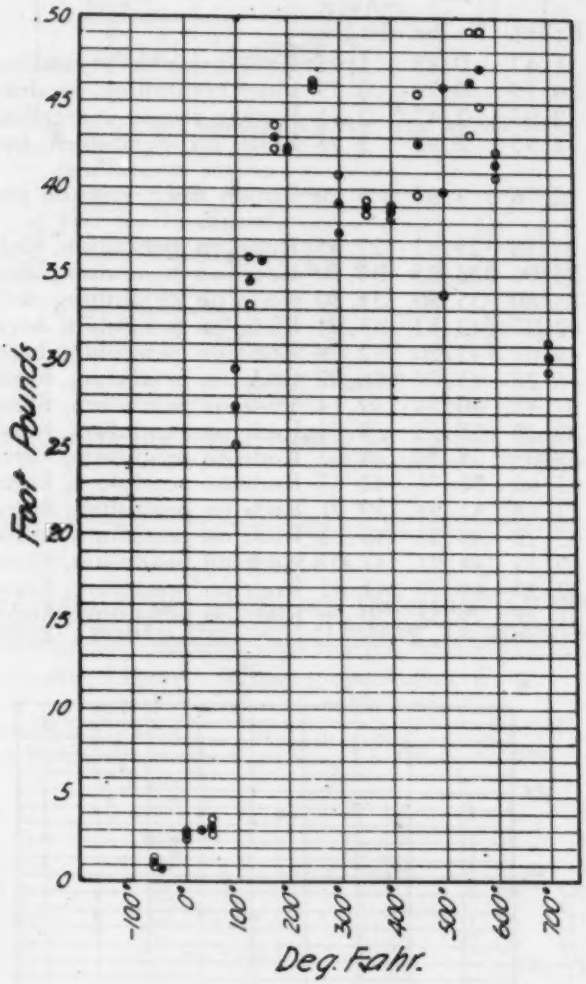


Fig. 8—Impact values obtained on annealed material tested at 20 different temperatures.

B1-1, B1-2, B1-3, B2-1, B2-2, B2-3. The Charpy test results are given in Table II.

The Charpy impact resistance of the material deformed in the "blue brittle" temperature zone, was thus shown to be but 15 per cent of the resistance of the nondeformed material. This preliminary experiment served as a guide in the experiments originally designed, which were carried out on different material of similar composition as described.

Experiment I

The annealed strips cut from the shear plate and marked as shown in Fig. 1, were cooled or heated to 20 different temperatures, bent and again flattened at those temperatures, and three Charpy test specimens were machined from each strip, thus giving three

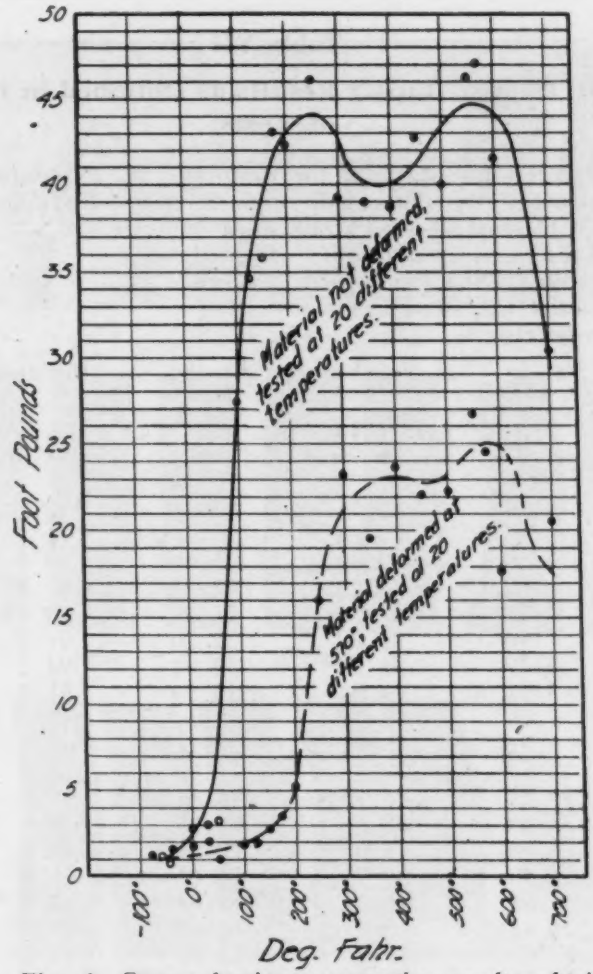

Foot Pounds
Deg. Fahr.
Material not deformed, tested at 20 different temperatures.
Material deformed at 570° tested at 20 different temperatures.

Fig. 9—Curve showing comparative results obtained in the impact tests of materials in different conditions.

test specimens for each temperature. The strips after deforming were cut as shown in Fig. 4. The notch was cut in a manner that would allow the most deformed section of the material to be in the rupture section of the test specimen. The temperatures at which the strips were bent or deformed are shown in Table III.

The strips from which test specimens were to be made were cooled below atmospheric temperature by immersion in an acetone

bath, the bath being cooled to 50 and 0 degrees Fahr. by surrounding it with a freezing mixture of ice, salt, and calcium chloride. The lower temperatures were obtained by additions of *carbon dioxide snow* to the acetone (carbon dioxide snow obtained by quick expansion of liquid carbon dioxide into a canvas bag).

Table VII

Comparison of Charpy Impact Results as Obtained in the Three Series of Tests

Temperature of Tests or Deformation Degrees Fahr.	Material deformed at 570 Degrees Fahr. and tested at 20 different temperatures.	Material not deformed. Tested at 20 different temperatures.	Reduction in impact resistance of deformed material.	Percentage Reduction	Material deformed at 20 different temperatures. Tested at 78 Degrees Fahr.
	Ft.-lbs.	Ft.-lbs.	Ft.-lbs.	Per cent	Ft.-lbs.
— 80	1.16	.....	.....	.....	....
— 58	....	1.15	.....	.....	3.45
— 43	1.43	0.79	(+0.64)	.....	3.60
— 40					
0	1.61	2.71	1.10	40.5	3.68
30					
32	1.89	2.95	1.06	35.9	3.31
50	1.03	3.20	2.17	67.8	3.18
100	1.78	27.35	25.57	93.4	3.01
125	1.90	34.60	32.70	94.5	3.31
150	2.79	35.80	33.01	92.2	3.58
175	3.51	43.04	39.53	91.8	3.11
200	5.16	42.28	57.12	87.7	3.01
250	15.91	46.02	30.11	65.4	2.92
300	23.11	39.14	16.03	40.9	3.05
350	19.55	38.96	19.41	49.8	2.62
400	23.59	38.63	15.04	38.9	2.30
450	22.08	42.65	20.57	48.2	2.09
500	23.30	39.91	16.61	41.6	2.30
550	26.61	46.22	19.61	42.4	1.89
570	24.45	47.07	22.62	48.0	2.05
600	17.63	41.45	23.82	57.4	2.18
700	20.51	30.36	9.85	32.1	2.09

The temperature of the strips in the acetone bath was determined by alcohol thermometers, one thermometer being in the acetone, and one inserted into a hole in a dummy specimen and packed with powdered magnesium. When the temperature of the acetone and the dummy specimen were the same, it was considered that the temperature of the strips was also the same.

Temperatures from 100 to 350 degrees Fahr. were obtained

in a constant temperature electric oven, the temperature being ascertained by mercury thermometers in the oven and packed inside a dummy specimen. Temperatures from 400 to 700 degrees Fahr. were obtained in an electric muffle furnace, and were determined by a platinum-platinum rhodium thermocouple inserted into a

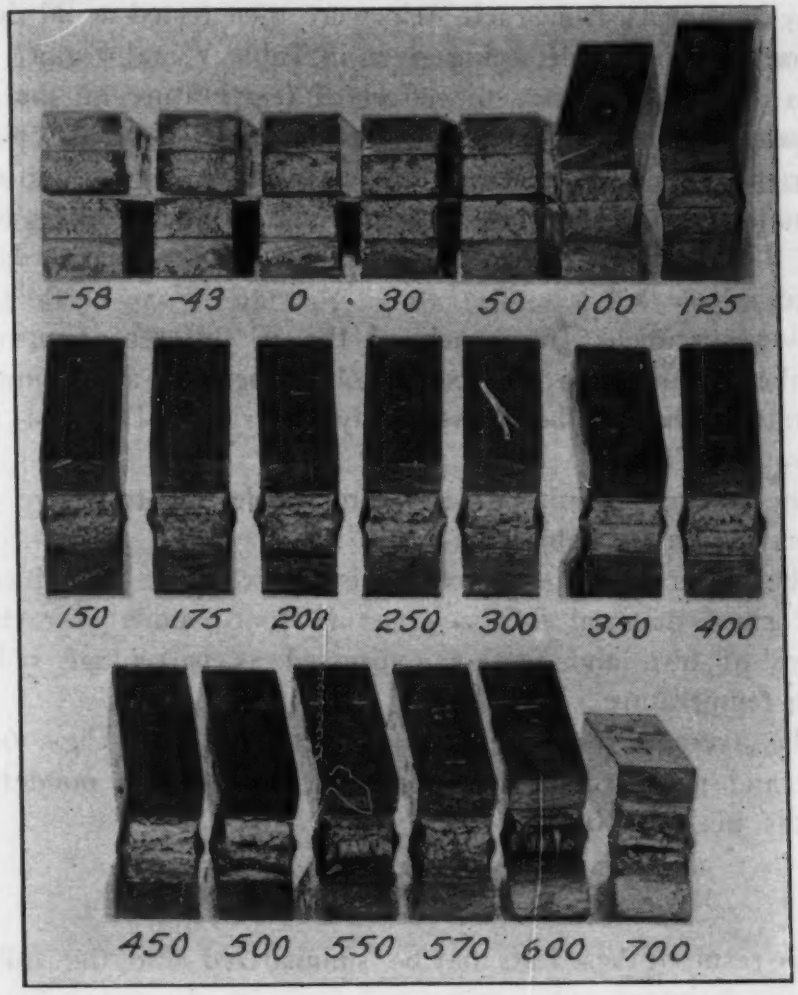


Fig. 10—Typical fractures obtained in the impact testing of undeformed material tested at twenty different temperatures.

dummy specimen. The actual temperatures of the strips during deformation were within two degrees Fahr. plus or minus the nominal temperatures. The Charpy test specimens were tested at a constant temperature of 78 degrees Fahr. The results are given in Table IV and Fig. 6.

Experiment II

Twenty strips marked 1A to 20X were then heated to 570 degrees Fahr., or the "blue brittle" temperature, and deformed by bending and flattening as described. Three Charpy specimens were machined from each, care being taken to cut them in exactly the same manner as the specimens from strips 22 to 41. The three Charpy specimens from each strip were then tested at 20 different temperatures, the results being given in Table V and Fig. 7.

In order to compare the effect of temperature on the impact resistance of this plate steel in the nondeformed annealed condition, 40 Charpy bars were machined from a remainder of the original plate material which had been annealed in a similar manner; namely, heated 1700 degrees Fahr., held one-half hour and cooled in the furnace.

Two specimens from each of the 20 different temperatures were then tested; the method of obtaining and ascertaining the temperatures having been previously described. The test results are given in Table VI and Fig. 8.

The average results of the three series of tests are placed for comparison in Table VII.

The difference in impact value between the deformed and nondeformed material is also given in foot-pounds at each temperature of test, and further expressed as percentage reduction at each temperature.

The average results are shown graphically in Figs. 6, 7, 8 and 9, and photographs of typical fractures of the nondeformed materials in Fig. 10.

Conclusions

The result of these tests may be summarized into the following four main points:

1. Material of the type described when deformed at temperatures between —58 and +700 degrees Fahr. has a general low Charpy impact value when tested at atmospheric temperatures. Such values are from about 7 to 14 per cent of the impact resistance shown by the nondeformed annealed material (Experiment I).

2. Material of the type described, when deformed at 570

degrees Fahr. or at the nominal "blue brittle" temperature has a lower Charpy impact value when tested at all temperatures between —58 and +700 degrees Fahr. than nondeformed material (Experiment II).

3. The effect of deformation at temperatures from —58 to +700 degrees Fahr. in reducing the Charpy impact value at atmospheric temperature increases as the temperature of deformation increases.

4. Deformation at 570 degrees Fahr., or "blue brittle" temperature, reduces the Charpy impact value at temperatures from —80 to +700 degrees Fahr., 32 to 94.5 per cent compared with nondeformed annealed material tested at similar temperatures. The reduction is less at low temperatures, reaches a high point at about 125 degrees Fahr., falls at about 400 degrees Fahr., rising at 600 degrees Fahr. and again falling at 700 degrees Fahr.

A CORRELATION BETWEEN THE MECHANICAL HARDNESS AND THE MAGNETOSTRICTIVE EFFECTS OF FERROMAGNETIC SUBSTANCES

By S. R. Williams

Abstract

This paper describes a method of determining the physical properties of metals through magnetic means, and briefly describes the relative merits of the X-ray and magnetic means of determining flaws in metals.

The author describes the Joule effect or that property of the metal which permits it to change its dimensions when magnetized.

Experiments are discussed wherein an endeavor was made to relate magnetostriction and hardness of ferromagnetic substances.

Introduction

IN THE effort to discover relationships between mechanical and magnetic properties, the experimental fact seems to have been established, that any modification of a physical or chemical quality of a substance is accompanied by a variation in its magnetic characteristics. The experimental evidence for this broad statement does not seem to be so clear for diamagnetic and paramagnetic substances as for ferromagnetic bodies, but this is doubtless due to the relative weakness of the first two of these qualities.

If the above is correct, it then should be possible to make a determination of any physical property through magnetic measurements. In particular it should be possible by magnetic means, to classify a given group of rods, in respect to their hardness. Such a study constitutes a phase of an important and rapidly developing field, known as magnetic mechanical analysis.

Success of Magnetic Mechanical Analysis in Detecting Flaws in Steel

Magnetic irregularities always occur in the presence of de-

A paper by S. R. Williams, department of physics, Oberlin college, Oberlin, Ohio, and presented before the Pasadena meeting of the American Physical Society, May 5, 1923.

fects in ferromanganetic substances. McCann and Colson[1] were pioneers in this field, when they showed that elevator cables could be inspected magnetically, and flaws detected which could not otherwise be located by ordinary examinations. The magnetic method of locating mechanical defects recommends itself because it does not destroy the specimen examined. The only other method offering this advantage is the X-ray, and those investigators who have worked on this problem using both methods of examination, indicate that the X-ray method has limitations in the inspection of large pieces due to the great absorption of the X-rays by the materials. Burrows[2] has demonstrated that magnetic analysis is useful in studying the mechanical conditions of materials, such as railroad rails. Application of magnetic analysis to the testing of ball bearing races and the location of flaws in rifle barrels by Sanford[3] and his co-workers, is confirmatory of the increasing use of this method for investigating the physical conditions of steel.

Success of Magnetic Mechanical Analysis in Studying Physical and Chemical Transformations in Heat Treatment of Steel

Branching out into other fields of magnetic mechanical analysis, Honda[4] and his associates, have done some excellent work in following the physical and chemical transformations which take place in iron or steel on heating or cooling. This work is a distinct contribution to the field of magnetic analysis, to say nothing of its significance for the metallographist. Not only has the critical temperature of the various transformations of different steels been determined, but the character of these transformations has had a flood of light thrown upon it. There is no time lag as in the thermal method of investigating these transformation points. The method, therefore, offers some real advantages to the metallographist, for in the ordinary processes of studying the transformation points of certain substances, cementite, for example, it is only by means of magnetic analysis that sufficient differentiation is obtained, to show distinctions between the various conditions.

1. McCann and Colson, West. Elec., 43, p. 76-77, 1908.
2. Burrows, *Scientific Papers*, Bureau of Standards, No. 272, March 20, 1916.
3. Sanford, *Proceedings* of the American Society for Testing Materials, twenty-second Annual Meeting, 1919.
4. Honda, *Journal* of the Iron and Steel Institute, September, 1918; *Science Papers*, Tohoku Imperial University, Vol. 5, pp. 285-295, 1916; Vol. 6, p. 23, 1917.

Nusbaum[5] has given some curves showing definite relations between drawing temperatures and maximum coercive forces for the same drawing heats. Gebert[6] has shown similar curves for nickel steel, and it is very evident that the magnetic mechanical analysis tells a great deal more about what has happened to the steel in the various heat treatments than do the hardness tests. Spooner and Kinnard[7] have worked along similar lines.

New Type of Magnetic Mechanical Analysis

Ferromagnetic substances change their dimensions when magnetized. This phenomenon is known as magnetostriction. It may

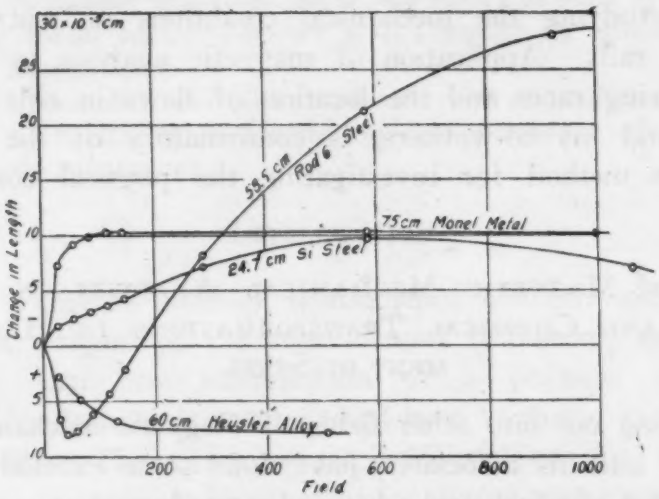


Fig. 1—Curves showing the manner in which various ferromagnetic substances change their length as various field strengths are applied.

be illustrated by the special case discovered by Joule[8], that an iron rod changes its length when magnetized. In Fig. 1 is shown the manner in which various ferromagnetic substances change their length as various field strengths are applied. The Joule effect is a direct connection between magnetic and mechanical properties and should be the most significant of magnetic phenomena for the prediction of the mechanical properties of ferromagnetic bodies. In the endeavor to relate magnetostriction and the hardness of ferromagnetic substances, experiments were performed in which five similar steel rods, drawn at different temperatures, were tested

5. Nusbaum, *Proceedings* of the American Society for Testing Materials, twenty-second Annual Meeting, June, 1919.
6. Gebert, *Journal* of the American Society for Testing Materials, June, 1919.
7. Spooner and Kinnard, *Proceedings* of the American Society for Testing Materials, p. 883, Vol. 21, 1921.
8. Joule, Philosophical Magazine, pp. 76-225, Vol. 30, 1847.

with respect to the changes in length occurring when a magnetic field parallel to the rods, was increased from zero upward. These rods were supplied by Dr. Whittemore of the Bureau of Standards, who also furnished data as to the heat treatment, hardness and chemical composition.

The chemical analysis, heat treatment and hardness numbers of the rods are as follows:

Chemical Analysis

Rod No.	Carbon	Manganese	Phosphorus	Sulphur	Silicon
1	1.34	0.37	0.010	0.018	0.13
3	1.27	0.27	....	....	....
4	1.23	0.32	....	....	....
5	1.35	0.35	....	....	....
6	1.27	0.37	....	....	....

Heat Treatment

	Hardening All specimens oil quenched		Tempering All specimens air cooled		
Rod No.	Degress Cent.	Degress Fahr.	Degrees Cent.	Degrees Fahr	Time
1	788	1450	Not Tempered		
3	788	1450	705	1301	15 min.
4	788	1450	427	800	15 min.
5	788	1450	565	1049	15 min.
6	788	1450	705	1301	2 hrs.

Scleroscope Hardness

(average of ten readings)

Rod No.	Scleroscope Readings
1	70.7
3	34.6
4	51.9
5	42.8
6	30.8

The hardness number reported for each rod, is the average of 10 readings taken at intervals on each rod. Rods 1, 4 and 6 appeared to be softer near the numbered end as is shown in the following table:

Scleroscope Reading

Rod No.	End not numbered	Numbered end
1	78	32
4	55	34
6	42	35

Rockwell Hardness Number

1	69.7
3	62.9
4	67.4
5	66.7
6	54.6

The Rockwell hardness number reported, is the average of four readings, two on each end of each rod.

These rods were suspended in a vertical solenoid, one meter in length, and the change in length of the rods measured, as they were magnetized from zero upward, by a combined mechanical and optical lever. This method[9] has been described elsewhere, but for this particular work a new and more sensitive outfit was construc-

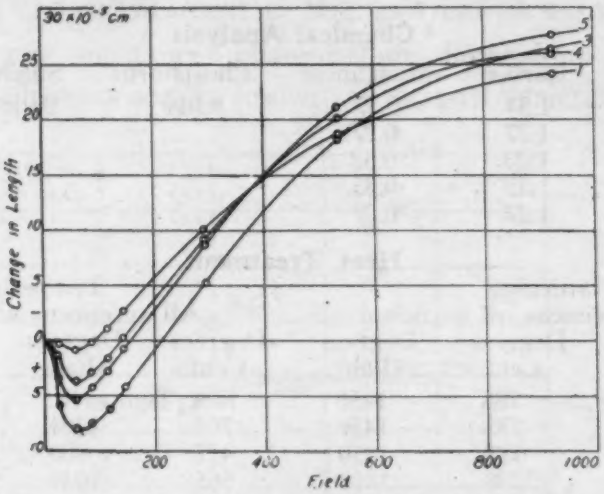


Fig. 2—Curves showing the manner in which steel rods having the same composition, but different annealing temperatures, change their length due to a magnetic field.

ted and gave a magnification of the changes in length equal to 65,000. This means that one could detect a change in length of the rod as small as 1/30 to 1/35 of a wave-length of sodium light. The dimensions of the rods were 58.5 centimeters in length and had a diameter of 0.57 centimeters.

The solenoid, rod and measuring outfit were placed on a stout wooden shelf, which in turn was bolted to the foundation wall of the laboratory. The spot of light which recorded the changes in length was very steady, and measurements could be made while the liquid air generator and the ventilating system were running at full speed. It was found that a heavy outside foundation wall or any heavy bearing wall was a much better place upon which to mount such a sensitive measuring device, rather than mounting it on a pier set in the ground and floated on sand.

Results

In Fig. 2 is shown the way in which the different rods, changed

9. Physical Review, p. 258, Vol. 34, 1912.

their length due to a magnetic field. If the values of the maximas of the elongations, shown in Fig. 2, are plotted against the scleroscope readings, as shown in Fig. 3, it at once appears that there is a definite relation between the Joule effect and hardness. The curves in Figs. 2 and 3 indicate that the softer the specimen of steel, the greater is the value of the positive elongation of the rod.

From the table showing the heat treatment of the rods, it will be seen that rod No. 6 was reheated for two hours instead of fifteen

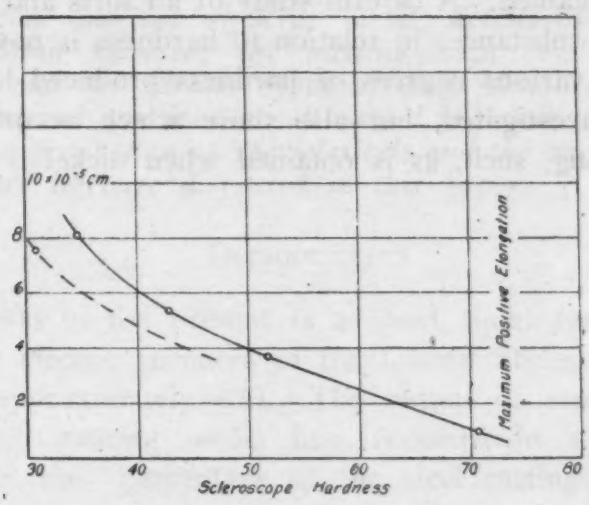


Fig. 3—Curves in which the values of the maximas of the elongations are plotted against the scleroscope readings.

minutes, as were the other rods. From Fig. 3 it may also be seen that rod No. 6 would be on another curve indicated by the dotted line which would coincide with the main curve at 70.7. This is substantiated by some recent work of Rawdon and Epstein[10] in which they show that with increased length of tempering period, i. e., from 15 minutes to 2½ hours, that the scleroscope hardness is reduced.

Rod No. 5 showed some peculiar effects in that it took a great many more cyclic changes before consistent readings were obtained for the Joule effect. The first measurements showed very small initial elongation, but as the rod was put through more and more cyclic magnetic processes, it gradually settled down into the type of curve shown in Fig. 2. From the interpretation put on the curves, this means that it is possible to anneal or soften a steel rod by "working it" magnetically. It would appear that rod No. 5

10. Rawdon and Epstein, *Scientific Papers*, No. 452. Bureau of Standards. Fig. 18, p. 405.

was in a more unstable condition than the other rods, for the first set of measurements on the other rods did not vary much from the later ones. All the curves for the Joule effect in this investigation are for the condition that the rods have been put through numerous magnetic cycles, i. e. magnetization—demagnetization—magnetization in opposite direction—demagnetization, etc.

It appears then from these preliminary studies, that a more extensive correlation between magnetostriction and hardness can probably be obtained. A careful study of all sorts and conditions of ferromagnetic substances in relation to hardness is now under way. Not only are various degrees of hardness produced by heat treatment being investigated, but also those which occur due to mechanical working, such, as is obtained when nickel is hardened by cold rolling.

These investigations were carried on in the Norman Bridge Laboratory of Physics. The author wishes to thank the director, Prof. R. A. Millikan, for placing at his disposal the apparatus necessary to carry out the experiments described.

THE MANUFACTURE OF ACID ELECTRIC STEEL FOR COMMERCIAL CASTINGS

By Larry J. Barton

Abstract

This paper discusses in much detail the manufacture of acid as made in the electric furnace, for use in the production of commercial castings. The selection, segregation and use of scrap metal; details of charging the melting furnace; the melting-down conditions involved, and the various types of slags obtained in both good and bad practices, are discussed in detail.

The production of special steels and the various alloy steels are likewise discussed in this paper.

Introduction

FROM 1906 to the present is a short time, yet in that brief space the electric furnaces of the United States have increased from 1 to approximately 430. The output of steel for castings made in such melting media has increased in a corresponding manner, until the percentage of the steel castings made by the electric process is now about 15 to 20 per cent of the total output.

The reasons for this rapid increase are many; a better grade of steel produced; possibility of attaining temperatures of the metal far higher than can be produced by any other system of melting; the adaptability of the electric furnace to the production of alloy steel castings, and the reclamation of a large percentage of the costly metal necessary for heads, gates, etc., all economic points favoring the electric process. As time passed, and experience increased on electric furnace melting, it was seen that the highest possible results to be obtained in the manufacture of steel castings were to be obtained from acid lined furnaces rather than from those operating under basic or neutral conditions.

The greatest point in favor of the acid process was its comparative cheapness. Due to the elimination of costly slag conditions, together with the ability of eliminating basic vapors from a partially lined acid furnace, it was found that the time of melting

A paper by Larry J. Barton, consulting metallurgical engineer, New Orleans, Louisiana.

on the acid hearth was less than on basic; the cost of power, refractories, and electrodes was considerably less; the tonnage to be obtained over a given period was far greater, with the corresponding saving in labor and fixed charges; the quality of the metal was as good, or better, the acid metal seeming to offer a freedom from defects commonly found in basic castings. Naturally, the foundries engaged in commercial casting production quickly gravitated to the use of the acid furnace. At first, considerable trouble was experienced, as the acid process was considered as nothing but a method of remelting, superheating, and alloying, and was operated as such. As more competent men became available, and were employed on electric furnace melting, it was found that this process was considerably more than one of remelting, in fact it was soon determined that it required as much, or more, skill and metallurgical knowledge to regularly produce acid steel, as it did to produce basic steel.

The Selection, Segregation, and Use of Scrap Metal

The chemical processes of the acid furnace are such that there is practically no elimination of the two undesirable elements, sulphur and phosphorus. As most specifications call for a minimum figure for these two constituents, usually 0.05 to 0.06 per cent, it is essential that the scrap purchased fall enough within these limits so that the small increase due to melting shrinkage, will still give a final metal within the limits of the specification. The second point of great importance in the selection of scrap is that covering its general character of cleanliness. Iron oxide tends to combine with, or corrode an acid hearth, so it is necessary in the purchasing of scrap, to select such material as has a minimum of rust adhering to its surface. Consequently very light, or thin scrap is not desirable for this reason. The same item eliminates dirty scrap, such as heavily oxidized pieces, or those containing burned spots, etc. The third point is that of size of scrap; the charging door being only so large the piece must be small enough to be readily and quickly charged. The choice of scrap is, therefore, more limited than on the basic process. Such classes of scrap as clean, heavy, borings and turnings; heavy boiler plate; punchings; small sized steel bolts, and rivets; structural and rail butts; spring and coupler steel; heavy forge flashings, ingot butts;

broken steel castings; and similar classes of low phosphorus, low sulphur metal offer the proper conditions for the acid process.

As the scrap is unloaded from the cars it should be segregated according to several differences:

1. The phosphorus and sulphur contents of the scrap.
2. The carbon contents.
3. The size of the individual pieces.
4. The condition of the scrap, as regards rust, etc.

This separating of the different qualities is extremely important in the light of efficient operation, as any change in the make-up of the different charges will necessarily change the final product. As it is not economical to either boil down the carbon by additions of ore, or raise this element by adding carbon or pig iron, each charge should consist of such grades and sizes of scrap as may have been determined as giving the proper conditions of melt down.

In the preparation of a furnace charge it must be considered that a charge of light, dirty scrap will always melt down much lower in carbon, manganese, and silicon, than one consisting of large sized chunks. In the same manner a charge closely packed in the furnace will always give a quicker and cleaner melt down than will a charge of loosely packed material. In the making up of furnace charges there are certain of these points which must be closely watched. It follows that if every charge could be made up of exactly the same material with the same size and physical condition, each heat, if melted under similar conditions, should be approximately the same as the others when in a molten condition. While this cannot be accomplished, it can be greatly aided by keeping every charge uniform. The points to consider under this heading are:

1. Keep the phosphorus and sulphur within limits.
2. The proportion of light to heavy scrap should be kept the same.
3. The physical condition of the charge should be kept regular as regards rust, dirt, sand covered, and clean scrap.
4. The chemical composition of each charge including carbon, manganese, and silicon, should be closely regulated.

If these points are considered, and mastered, each heat will

require but a minimum amount of "working" before being brought to the finishing condition.

The Preparation and Care of the Furnace

Efficient operation assumes a minimum of delay from any cause whatsoever. Furnace experience has become so general that it is here unnecessary to mention any of the minor difficulties such as may be caused by the roof, electrodes, or side walls, however, some mention should be made of bottom making. Good steel cannot be made on a hearth which is continually giving trouble, and speedy and continued operations demand a hearth which will stand a great amount of abuse without failing. There are two fundamental methods of making an acid hearth; by burning or sintering in bit by bit; or by ramming the entire hearth at one time, and baking into. place. Having used both methods, the writer strongly recommends the latter, as giving a better hearth at a lower cost than the former.

Burning or Sintering Hearth

When a hearth is burned into place the furnace must be heated to a white hot condition when the sand or ganister can be very slowly added in small portions, each layer being thoroughly sintered into place before the next is added. This operation, for a three ton furnace will take from 12 to 24 hours, and use from 6000 to 10,000 kilowatt-hours, depending upon the care which is taken in the operation. To make a first class job the entire hearth should be made in one continuous operation, finally ending in one monolithic mass. The human equation here enters after a man has stood against such a white hot furnace for 10 or 12 hours his vitality has greatly lowered and he becomes careless. The result is apt to be a hearth but partially sintered in places, giving rise to considerable trouble when steel is being melted, by coming up in spots or patches. The writer has seen instances where an entire hearth came up in this manner.

Rammed Hearth

The second method is that of making a rammed hearth. The first step in this operation is the laying of the protective firebrick layer against the shell of the furnace. This layer usually consists of two courses laid flat, or five inches in thickness, of the best

quality firebrick. If good tight joints can be had it is satisfactory to lay dry, but if the bricks are dipped in some good refractory cement and rubbed into place, a superior protection will be had, as this cement not only makes a tight joint, but tends to close the pores of the bricks themselves. The question of expansion is immaterial on these bricks, as the amount of heat which they are to withstand is very small, they being but a protection in case of any unforeseen cutting of the hearth.

On top of these base brick are laid the refractories which make up the furnace walls. The next step is the actual ramming of the hearth material, one which is of the utmost importance. Opinions vary greatly as to the proper material to use for this purpose; the use of sand, crushed silica brick, and ganister being about equal. For binders we find such material as molasses, glutrin, fire clay, pitch and tar being used, together with certain classes of patented cements. The writer prefers a hearth made as follows:

About three wheelbarrows of ganister are well mixed, consisting of one about 4-mesh, one 8-mesh, and one practically a powder. This sized mix is one which offers a maximum of refractoriness, yet one which will thoroughly pack and form a tight mass. A light slurry of some high grade refractory cement is made up, and the ganister and slurry mixed until a tightly packing, moistened mixture, results. The exact consistency of this mixture will depend upon the manner in which it packs when rammed. If it is too moist more ganister must be added, and if too dry more of the slurry. The bottom bricks of the furnace are then heavily painted with some of this slurry, and the mixture thrown in the furnace. This mixture is rammed into place, using an air rammer, making as hard a layer as possible. As each batch is being rammed, another is being made up, and added at once so that there is no danger of any dry spot occurring between layers. The hearth is gradually shaped, care being taken to avoid any soft spots, and ramming every point as hard as possible. When the hearth is up to the proper thickness in the center, the mixture should be run up both the front and the back walls as far as possible. When completed the entire rammed surface is given a coating of sodium silicate, which will harden the refractory and hold it into place until baked.

The roof is now set, and a very slow wood fire started in the

center of the furnace, and kept going until the bricks gradually take up their expansion. This will take approximately 4 hours, when the intensity of the fire can be increased until it is roaring, and until there is a good sized bed of coals on the bottom. By this time the heat can begin to be felt on the bottom shell of the furnace. The fire is still kept up until the entire shell of the furnace is so warm that it is only with difficulty that the hand can be held on it. The time of heating is by now about 10 to 14 hours. A bed of medium sized coke about 6 to 8 inches in depth, is now thrown on the coals, and the electrodes lowered until contact is made. The power should be run on the lowest possible input until this bed of coke becomes white hot. Attention should now be given to the walls, care being taken to avoid any running of the refractories. The best points to watch are the corners of the jambs and arches, as they will begin to drip first. The power can now be shut off and thrown on at intervals, only enough being used to keep the furnace in a white hot condition. This period will take from 4 to 6 hours for a 3-ton furnace, and will consume approximately 1000 kilowatt-hours of electricity. If the furnace is to be operated at once the bed of coals can be raked out and the furnace charged for the first heat, if not the doors can be closed and the furnace allowed to cool down gradually.

Such a hearth is cheap and it is permanent. While the refractory cements cost more than does fire clay or the other binders, it gives a higher quality bond to the mass, and is without a doubt, the cheapest in the end. The hearth has been made at all times under a rigid inspection, its shape is correct, and it has been rammed to a uniform hardness, consequently there is no danger of any unlooked for weakness.

Charging the Furnace

The proper proportions of scrap used to make up an individual charge will vary according to the class of steel desired, but in any case it should be selected with a definite idea in mind. The different sizes should be so proportioned that a closely packed charge results, such a charge melting down much faster than one loosely packed. The greater the proportion of the charge directly under the arcs the faster the melting, and the less radiation losses, for this reason a deep, cup-shaped hearth is recommended in pref-

erence to the shallow hearth so common to basic operations. In a shape of this kind any hanging scrap on the walls will fall into the molten center by its own weight resulting in a saving of time and labor required to rake the walls clean. The best method of charging is to place the heavy chunks directly on the hearth, and then shovel in the light scrap which will pack in tightly between the chunks, making a very desirable charge. When shop scrap is used it is preferable to get it in on the bottom. For general steel casting work the writer has found that a charge of from 25 to 30 per cent of heavy scrap, the balance light, will give excellent melting down conditions. This charge should be made up of material averaging about 0.30 per cent carbon, and 0.50 per cent manganese, and depending upon the cleanliness of the scrap, certain additions of either sand or coke. If the scrap is fairly clean there should be no such additions; a charge of light scrap heavily oxidized will require about 10 pounds of crushed coke per ton in order to compensate for this excess oxide.

Melting Down

The furnace being charged, the current is thrown on at high voltage and the melting commences. At first there will be heavy clouds of reddish brown smoke issuing from around the electrodes denoting heavy surface oxidation, arising from the heavily rusted coating on the scrap. As the electrodes dig deeper in the charge a pool of metal will gradually form, and this brown smoke will gradually die down. At this particular point in the melting period there are certain indications which will clearly show conditions within the furnace and the greatest of care should be used in the melter's observation of the operations at this point.

1. *Proper Melting Down Conditions*

a. Where no coke is added with the charge.

In this instance the reddish brown smoke will gradually die down, giving way to a light, yellowish vapor, with occasional traces of the brown smoke. As soon as a fair sized pool is formed the flames will turn a yellowish color, with emissions of a light smoke, which will continue until completely melted.

b. Where coke has been with the charge.

As soon as a pool begins to form, heavy yellowish flames will come from around the electrodes, with very heavy clouds of

either dense white or black smoke. As soon as the influence of the coke ceases the flames and smoke will turn to the condition mentioned in class. "*a*."

2. *Heavily Oxidizing or Low Melt Down Conditions*

The flames coming from around the electrodes will be sharp, and of a reddish-blue color. There will be practically no smoke issuing from the furnace at all, the flames being very thin, denoting complete combustion of the gases within the furnace itself.

3. *Reducing or High Melt Down Conditions*

The flame, after the pool has formed, will be a luminous yellow, appearing extremely soft in texture, and accompanied with very dense clouds of white smoke. If reduction is extreme the furnace may even "snow" or give out dense clouds of silica ash coming from the reduction, and later oxidation and deposition, of silicon reduced from the slag.

4. *Bridging*

This is the most dangerous feature in the operation of an acid lined furnace, and one which requires the most watching. Often the scrap used is such that the electrodes rapidly dig through it, and make but a deep hole as they melt down. Consequently, there is but a slight pool in the hearth, with a roof of welded metal above. As the arc strikes against this small pool of metal it naturally heats it to a very high temperature, so high, in fact, that it is enough to start the hearth to slightly fusing. As this fused silica rises to the surface it is directly in contact with the arc. This arc, in combination with the carbon fumes from the white hot electrode, starts the silica to reducing, giving rise to a heavy vapor of silicon, which oxidizes to silica on exposure to the oxygen of the air, depositing the heavy greyish precipitate known as "snow." If this is allowed to proceed, the result will be that the electrodes will gradually dig deeper, until completely through the hearth. This is made possible by the fact that the upper layers of the charge are protected by the slag from the heat of the arc, and do not melt as the electrodes dig.

A furnace "snowing" during the first half-hour of the melt, or before the charge is completely molten, is a sure indication of "bridging." This is further shown by the heavy white smoke

coming from around the electrodes, coupled with the muffled or liquid sound to the arc. The furnace must at once be shut down and this bridged condition removed by breaking or prying loose, the above layers of the scrap. Often it cannot be budged and the electrodes must be raised and fresh metal added to the holes, level with the top of the original charge, when the furnace can again be started.

The appearance of the flame, coupled with the sound of the arc, and general appearances of the furnace constitutes to the experienced melter, a plainly written statement of conditions within his furnace. If the heat is melting down too high, his most natural step would be the addition of ore; if melting too low either coke or more slag should be added. Up to the point of complete melting, many valuable minutes can be saved by closely watching these signs, and the high grade operator will take advantage of every indication.

Conditions at the Melt Down

When the bath is nearly melted, a test should be taken with the ordinary test spoon, for both metal and slag, and their fractures closely examined. Experience has taught us that on the acid hearth, certain conditions always closely follow—that a certain carbon content will always be accompanied with a corresponding ratio in the percentage of the manganese and silicon, the proportions of these elements being constant in the charge. These figures will change according to the size and character of the scrap, the amount of slag volume and the rapidity of melting. The writer has very carefully studied this condition on the rapid melting 'Lectromelt furnace, and has plotted a chart, covering the results obtained from several thousand heats. This chart, as shown in Fig. 1, is based on a charge consisting of approximately 25 per cent shop returns, the balance being fairly clean boiler plate steel, the mixture being so proportioned as to analyze approximately 0.25 to 0.30 per cent carbon; 0.50 to 0.60 per cent manganese; and 0.10 to 0.15 per cent silicon.

In the manufacture of casting steels there will always be some percentage on the melt down which will give superior results in time and labor when refining. Such an analysis can be

considered as the standard, and any deviation from this figure must be taken care of during the finishing period. By far the best analysis of such a bath of steel is about 0.11 to 0.13 per cent carbon; 0.08 to 0.10 per cent manganese; and 0.05 to 0.07 per cent silicon. A bath of metal melting down to such an analysis contains a sufficient quantity of residual alloys to insure against over oxidization, and yet is low enough in these

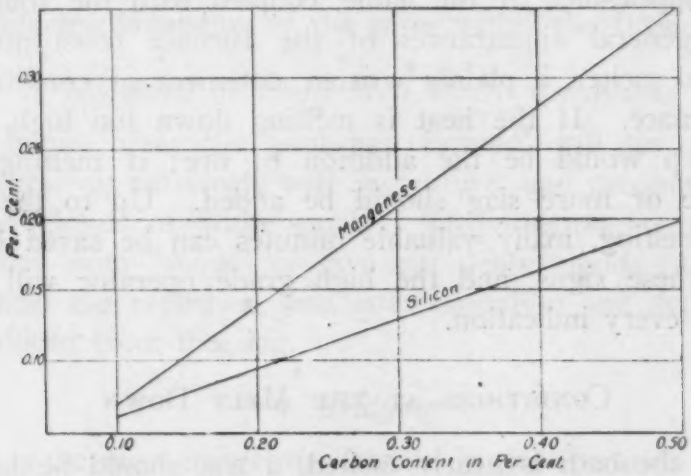


Fig. 1—Curves showing the corresponding ratio of manganese and silicon contents based upon a charge of approximately 25 per cent shop returns.

elements to allow of meeting the specifications for the softer steels, without any necessity of cutting down later additions, or using ore. Such a mixture as has been described will, if melted under correct conditions, give this analysis when molten.

Naturally if every heat melts down at this analysis, and equal additions of alloys are made, regular results will be obtained. The idea being to bring the molten bath to a certain figure, and then bring back, is without a doubt, the secret of well controlled analyses on the acid hearth. This given figure to be obtained on the melt down is not an arbitrary one, but is the average figure obtained by closely following a great number of perfect heats made under the above set of operating conditions. We know, however, that obtaining such a condition is not always possible, and we must determine what conditions will influence a change in melting to give a figure either higher or lower than that desired.

Low Figures on the Melt Down

This condition is easily shown when taking the first slag and metal test. The metal will be covered with splotches of oxide, and will spark heavily when poured into the chill mold. As soon as the mold is filled it will generally gas so badly that the steel will be forced out of the mold leaving but a shell of metal. The appearance of such a test is shown in test bar No. 1 of Fig. 2. If it does not have this particular appearance it will bubble badly

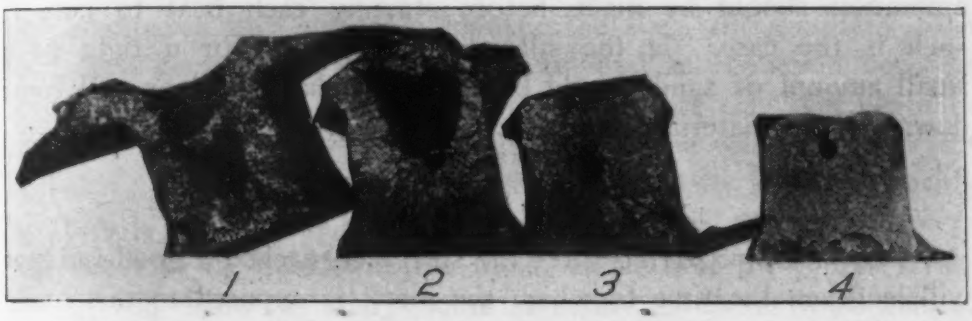


Fig. 2—Four fracture-specimens showing the complete progress of metal tests taken under bringing-back operations.

while solidifying and the fractured test will consist of nothing but a net-work of steel filled with gas holes, no crystalline structure being present. The slag accompanying such a test will be a very dark black, very thin and glassy. It will be very brittle, and to the trade is known as a "watery" slag on account of its fluidity. Such conditions are conductive to a poor quality metal, due to the fact that the steel has completely melted in an excess of gaseous or oxide matter. There is no doubt but what a certain amount of this oxide has actually dissolved in the iron itself which is almost impossible to remove no matter how severe the period of reduction, and while this may not show up as the familiar gas holes the fact remains that a great number of the "mysterious" cracked castings are directly caused by this nonmetallic inclusion.

Such a condition has been caused by an over supply of oxygen during the melt down, which has "burned" out nearly all the carbon, manganese, and silicon from the metal. This may have been caused by several items:

1. *Improper Calculating of the Charge*

This may have been due to such gross neglect as charging

a larger amount of dirty, heavily rusted scrap, or scrap of a very small size, than should have been added. The selection of each charge should be made either by the melter himself, or by one of his trained assistants acting directly under his orders.

2. *Excess Air Entering the Furnace*

This may have been caused by poorly fitting doors, or by small pieces of scrap on the sill not permitting the doors to shut down tight. Each door should make a snug fit on the sill, and an examination should be made before starting each heat to note if such is the case. If the sill is too irregular for a tight fit a small amount of sand should be so placed that the door will come down on this material insuring a tight seal.

3. *Delays During Melting*

Any delay occurring after the steel has reached a good red heat will lengthen the time to which the metal is exposed to this oxide condition. The result will be a heavy scaling of the metal due to the oxygen coming in either from around the doors, or through cracks in the roof, or around the electrodes. Such a delay may be caused by a breaking electrode, or by the power being shut off, trouble with the automatic control apparatus, etc. To prevent any such excess oxidation, especially when a good sized pool has formed, a light layer of sand should be thrown on the bath, and covered with a dusting of ground coke, which will protect the metal underneath from any air, by acting as a protective blanket. In any serious delay where it may be several hours before the power can again be turned on, there should be no sand added or it may solidify and cause insulation of the charge, by making a slag scum over the raw metal. In such an instance it is better to use coke alone, the bath being dusted rather heavily, the greater part of this carbon later burning away with no adverse effect on the analysis of the metal itself. It is also good practice in long delays to add a little manganese as soon as melting starts to take care of any oxide which may have come into direct contact with the metal.

Bringing Back an Over-Oxidized Heat

The first step will be to add several good sized shovels of crushed coke, together with, sufficient ferromanganese to raise

the bath to at least 0.20 per cent manganese. These items will at once furnish a heavy reducing atmosphere which will offer a means of combining with the oxides present. Enough slag-making material should be added to adequately cover the metal, and the bath should be heated up. The steel should never be heated without first making sure that reducing conditions are correct, or the result will be dissolved oxide in the metal, this being rapidly taken up and held in solution under conditions of high temperature. As the furnace heats up the exact changes taking place can be easily determined by taking frequent metal and slag tests. If conditions proceed in a desirable manner the slag will gradually turn to a dark green, then to a light green, and as reduction becomes severe, and the metal becomes highly heated the slag will begin to thicken and turn to a light yellowish green, the color of a perfect acid slag. As this proceeds the metal will gradually lose its covering of reddish oxide spots, and will assume a clear silvery color. It will begin to lie quietly in the mold, and a test piece upon fracturing will show a fairly solid structure, with a well defined crystalline appearance. The complete progress of metal tests taken under such bringing-back operations is clearly shown in Fig. 2.

Under certain conditions where over oxidation is extremely severe the reactions will slightly differ. The metal will begin to boil as it heats up, and the slag will foam up so much that it is very apt to be forced out of the doors. The power should be shut off, and as much of this slag raked from the furnace as possible. The power can then be turned on, and several good sized pieces of pig iron added. This will raise the carbon and silicon enough to remove a large part of the oxide, when the heat can be treated as before mentioned with perfect success. The most important point to remember in any heat of this kind is never to allow the metal to reach a high temperature, unless under conditions of heavy reductions, where the oxide is removed as the temperature rises, and before it has had the opportunity to reach the state of a fixed solution in the steel itself.

High Figures on the Melt Down

This is evidenced by the high carbon test, the metal lying quietly in the spoon, and giving a rather sound fracture. The slag accompanying this metal will ordinarily be thick and of a

distinct greenish color. The flames from around the electrodes will be very soft yellow, and highly luminous. Under very heavy reducing conditions the furnace may even "snow." This condition may be caused in several ways:

1. Improper selection of the charge, allowing too high a proportion of high carbon scrap or sand-covered shop scrap to the lighter metal. There may be too large a proportion of very clean scrap, or scrap in large sized pieces, with no addition of ore being made to compensate for these features.

2. There may have been a piece of electrode break off without its being noticed, causing reducing conditions to commence.

3. The electrodes may have dug, causing an extra amount of slag to be on the metal, and reducing this silica so fast that all of this silicon was used to reduce the oxides, the normal alloys of the charge not being affected.

4. There may have been a large amount of slag making material thrown in with the charge, without cognizance being taken of its already high percentage nature. There may have been an extra amount of patching done on the previous heat, part of which has dislodged and entered the slag.

Regardless of the cause the result is the same, that the percentages of the alloys is too high, and unless lowered, will cause the heat to come down too hard, and over the desired specifications. The appearance of such a metal fracture is shown in test bar No. 1 in Fig. 3.

Bringing Back a "High" Melt Down

The first step is to rake off as much of the viscous slag as is possible, consistent with time and economy. Ore should then be added, lumps of medium size being used, and small portions added at a time. In these additions it is better to feel one's way by frequent additions of small size, than to add a heavy charge at one time, and stand the chance of having a serious boil with its attendant difficulties. In adding ore it must always be remembered that its action will not commence at once, but will require several minutes until its cooling effect on the metal has been overcome. Another point about the adding of ore is that there may still be

considerable action left in the bath, even after the effect of the ore has apparently been exhausted. This is due to the fact that certain parts of the bath may contain considerable oxide, but may be too cold for the action to operate. To overcome these points add ore slowly and as soon as each addition begins to work, allow it to come to a steady boil before making any further additions. A

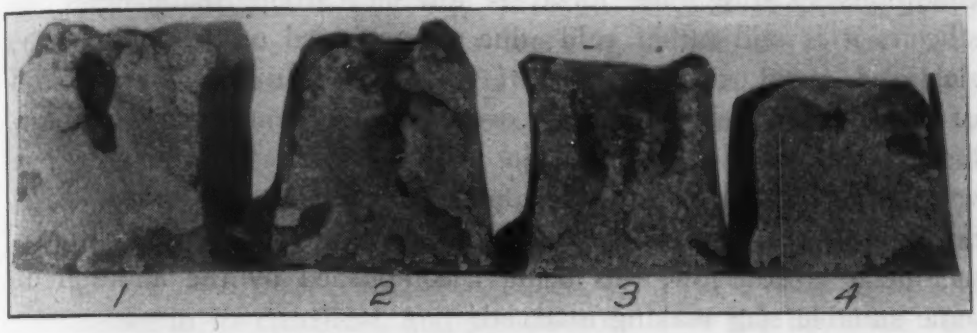


Fig. 3—Fracture tests. No. 1—heat too hard. No. 2—heat when properly boiled down to desired composition. No. 3—fracture of perfect melt-down. No. 4—fracture of perfect melt just before tapping.

boil handled in this manner will be nothing but a steady bubbling, but will have more result in lowering the carbon than would a violent action. When the carbon is down to approximately its desired point, do not add any alloys or slag, but allow the metal to heat up, and use a rod to determine whether there are any accretions on the hearth. If clean, the bath should be allowed to heat for several minutes until any last traces of the ore have had a chance to work free, then the heat can be placed under its finishing slag.

After a heat has been worked down in this manner there is one other point to consider before adding any slag; that of the volume of slag at present in the furnace. As oxide in high silicon metal tends to form slag in two ways; by combining with the silicon to form silica, and by its corrosive action on the walls this point must be carefully watched in order that the final slag may not be added in too great a quantity. It must be considered that a highly oxidized slag is very thin and watery, and there may be a considerable quantity present, yet it may appear as if the bath was practically bare. When this oxide has later reduced and the slag begins to thicken what may have appeared as insignificant, may prove to be of considerable extent.

Test bar 2 in Fig. 3 shows a fracture after being boiled down

to the desired composition. Test bar 3 shows the fracture of a perfect melt down; while test bar 4 shows the appearance of this perfect heat just before tapping.

Finishing the Heat

At this particular time in the period of melting, we have certain conditions existing; the metal is low in carbon, manganese and silicon; it is still rather cold; due to contained oxide, both in the slag and metal, the latter is of a "wild" nature. The question of low temperature is easily overcome by continuing the heating, but a heat of steel made in this manner would be of a very low grade due to its proportion of dissolved oxide. The first step is to therefore reduce the oxide while the temperature of the metal is still low, this being accomplished by the addition of some suitable slag making material.

For this purpose there are many materials in common use; old floor sand, crushed brick, or almost any form of siliceous material proving satisfactory. The material used should be of a small size and perfectly dry, and should be free of any iron oxide or small pieces of burned iron or sand. The material is carefully spread over the bath, the exact amount depending upon the conditions under which the heat has melted, enough being added to furnish a blanket to the metal, and to offer the required reduction as the temperature rises. After this slag has been in the furnace about five minutes the door should be opened and an inspection made, the slag being well rabbled if any tendency is shown of the slag lumping.

At this time the flames issuing from around the electrodes will be rather sharp, and of a reddish blue color, but without any appreciable amount of smoke. However, as soon as this slag is added the flames will drop down to practically nothing, and dense white smoke will pour from the furnace. As the slag melts down and diffuses over the bath this white smoke will gradually change to a yellowish brown vapor, accompanied by the yellow, luminous flames denoting the beginning of reduction. This condition also denotes a heating up of the metal and a test should again be taken.

The metal will still be cold, and the slag should still contain an appreciable amount of oxide. Its color should now be a dark green, having a medium consistency. If it is still thin, but green, more slag should be added. If the slag still shows black 10 or 15

pounds of ferromanganese should be added together with a little coke. If the fracture test shows a very low carbon, enough pig iron should be added to bring its content to at least 0.15 per cent.

From this period on, tests should be taken with regularity every four or five minutes, both slag and metal being examined. As the bath heats up and deoxidation proceeds, this slag will gradually turn to a lighter green color, until perfect conditions are reached, when the slag will be of a distinct yellowish green color. When this color appears the slag should be rather thick and tough; it should show a wrinkled surface on the test spoon, and should string in long streamers from the handle of the spoon as the metal test is poured. The surface of these stringers should be wrinkled and seamed. This is the final and absolute test for the slag. The metal accompanying such a test should be free from any of the reddish brown oxide spots on its surface, appearing mirror-like in its clearness, and should pour over the lip, with very little sparking, in a clear blue stream. The test piece will not be absolutely sound, but should not contain any apparent blow holes on fracturing, but should show a clear sound structure especially around its rim where it has chilled against the iron mold. If the above conditions exist the heat is ready to be brought to analysis and tapped. There are, however, other conditions which may exist at this point, and a heat of metal should never be poured under any but perfect conditions, especially if intended for work which must be machined.

Oxide Slags

Often it happens, through the metal becoming over oxidized, that at this point where the metal is getting very hot, the slag still shows black and thin. A metal test taken will be very wild, and may even foam up out of the test mold. Ferromanganese and coke should be added and heating continued. If this turns the slag a green color it is allowable to add more slag material to thicken the slag. If the black color still exists small additions of pig iron, manganese, and coke will be required until the last trace of free oxide is dispelled when the slag will begin to take its proper color and the heat can be safely brought to a finishing temperature.

Slags Too Thin

If there is insufficient slag body on the metal at this time it

will be noticed by the slowness of the metal to heat up, the bath seemingly being incapable of reaching its proper temperature. The slag will show a proper green color, and the metal will be of a favorable character. The addition of more slag material will quickly bring such a heat to its proper pouring condition.

Slags Too Thick

This is a serious matter, especially if occurring while the temperature of the metal is still low. The slag is very thick and heavy, and the arc has difficulty in breaking through to the metal. The furnace may even "snow." If the slag has merely lumped a small addition of lime or limestone and a rabbling will eliminate this over reducing condition. If, however, the slag volume is too large, part of it must be removed by raking from the furnace or the result will be a rapid reduction of silicon into the metal with the chance of having an "off" heat.

Oxidized Metal

It may be perfectly possible to have a perfect slag and still pour a "wild" heat. This may sound peculiar, but is easily explained. In the acid process the slag itself is the main deoxidizing agent operating by absorbing the oxide from the metal, bringing it to the surface where its oxygen content is eliminated, freeing silicon which returns to the metal for further reduction. We thus have three free powerful deoxidizing elements, iron, manganese, and silicon, each of which possesses a potential oxide carrying power. As these metals are freed from their charge of oxygen they return to the bath and absorb another load, this process being repeated until the bath has been freed of its oxide. While the slag may at times show a perfect color, it is possible for sections of the bath to still contain oxide, they being in the lower parts of the hearth where the slag is rather late in penetrating. The solution is to hold the heat until the slag shows a perfect condition for at least two consecutive five-minute tests. Oxide in the metal is easily observed by noting the surface as it is brought from the furnace in the test spoon. If oxide is present there will be small reddish brown spots which appear and disappear on its surface, the steel sparking when poured. If free from oxides the metal will have the customary mercury like ap-

pearance with a surface as clear as a steel blue mirror. Every heat should always be allowed to melt under a perfect slag for from five to ten minutes when it can be safely poured.

Bringing the Heat To Its Tapping Condition

The slag being correct, and the metal being near its desired tapping temperature, a final test fracture can be taken and examined for final additions. Whether the fracture test or chemical method is used is immaterial, the point here being that the first step is bringing the carbon to its specified percentage. Recarbonizing can be done in several different manners; pig iron can be used, being added at this point; carburite is permissible; immersing the electrodes in the metal with the current off is standard practice at many shops. The latter is too uncertain, and rather expensive, and for ordinary operations I strongly favor the use of washed metal, or low silicon low phosphorus pig iron. This is cheap, is easy to add, and is as exact as is possible to obtain with any other method.

The addition of the manganese will be dependent upon what process is to be used in bringing up the silicon. If the silicon is to be brought to specification in the standard manner; either by adding in the ladle or to the furnace, the manganese should be added to the furnace about 3 or 4 minutes before tapping, the material being used in good sized lumps, moistened in order to kick through the slag.

In making the highest grade of steels, especially those which are to have considerable machine work done on them, the best manner to introduce the silicon is by reducing it from the slag. This is, however, rather uncertain, and should never be attempted unless the melter is familiar with the peculiarities of this operation. The salient features of such a process are to thicken the slag by the addition of siliceous material, heat to a high temperature, and allow the slag to reduce the desired amount of silicon into the metal, the heat being tapped when the silicon is of the proper percentage. The difficult part of this operation is the proper judging of the silicon content, any mistake, or delay in tapping resulting in a silicon too high to meet specification. Steel made in this manner is of extreme quality inasmuch as absolute deoxidation is performed by the silicon in its nascent state, in which condition its affinity for any oxides is very powerful.

This reducing action can be quickly stopped if desired, by the addition of lime, sufficient being added to bring back the slag to a fluid condition, in which state it becomes incapable of reducing silica. This reduction of silicon if properly controlled, offers one of the greatest assets to the acid furnaces, but is possible of use only in the hands of an experienced operator. This reduction can be accepted as coming under the following phases:

1. Reduction from the siliceous hearth material, the action being caused by either iron, or carbon, from the metal itself.
2. Reduction from the increased silica contents of the slag.
3. Reduction from the silica of the slag by carbon, coming either from the electrodes, or from coke added to the furnace.
4. Reduction due to increased temperature.

Judging the Quality of the Metal

In the steel foundry there are always certain castings to be poured on every heat which must have absolutely sound metal. Many of these jobs contain considerable core work, and a heavy loss would be entailed upon the foundry if one of these castings were to be cast from metal with any tendency to wildness. There are instances where heats are poured under perfect conditions, where the metal appears to be of good soundness, and where the slag has the proper color and viscosity, yet the metal may prove "wild." This is generally due to carelessness, in that too much haste was used and tests may have been taken in a careless manner. To obviate such occurrences the writer has developed several visual tests which will demonstrate the soundness of the metal with no possible chance of error.

1. *Condition of the Slag Hanging to the Furnace Spout After the Ladle Has Been Filled*

If the metal is perfect the slag will adhere to the spout in long streamers, showing a high viscosity. Fig. 4 shows the appearance of the proper slag conditions. A heat upon which this condition exists may be safely poured into any class of work with the expectation that absolute freedom from gases exists.

2. *The Dry Sand Test Bar*

There are, however, instances where due to the fluidity of the slag, the metal may be of a perfect character yet there will be no slag streamers on the spout. Such a heat as this should

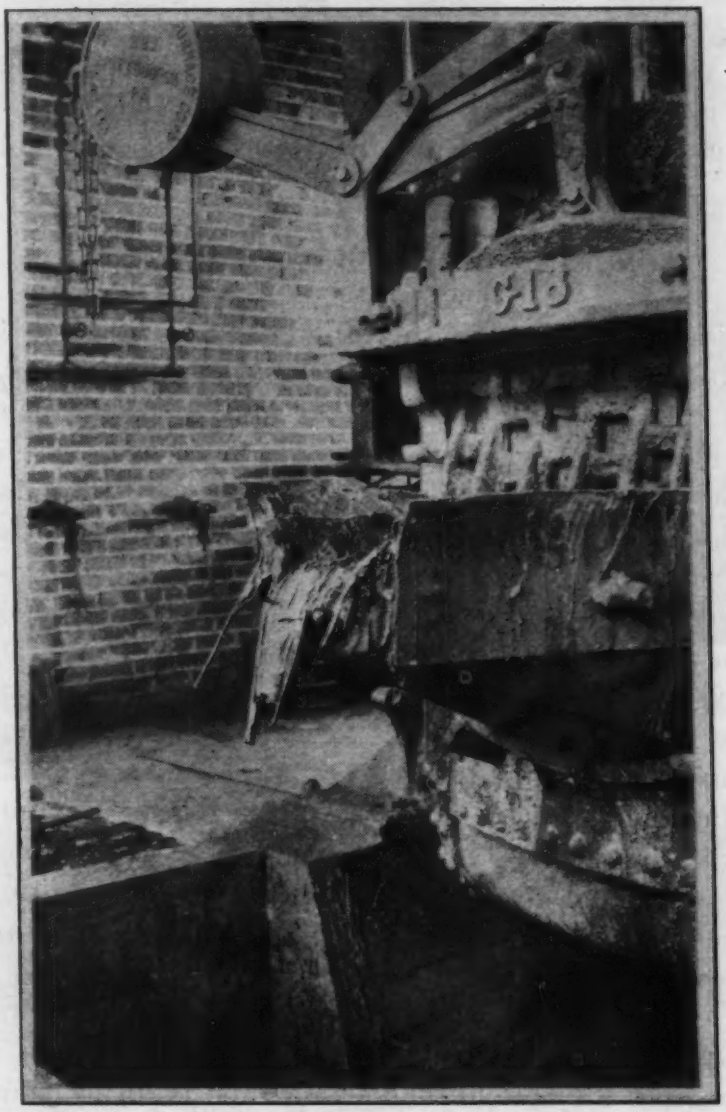


Fig. 4—Shows a perfect slag condition when the slag will adhere to the spout in long streamers.

be opened up over some class of nonmachineable casting, and as soon as the stopper is working properly a dry sand test bar should be poured, rapidly shaken out, water quenched and broken. Perfect metal will have the absolute soundness of fracture as shown

in Fig. 5. A very good size bar is one about 1.5 x 3 inches and 12 inches long. This test bar operation will take about 2 or 3 minutes, and may be the means of saving a great many dollars a year on defective castings. Figs. 6 and 7 show the appearance of a perfect slag and the fracture of same. Note the toughness of the streamer, and its wrinkled surface. Note freedom of gas from slag fracture. Fig. 8 shows chips turned from an unannealed casting poured under the slag condition as illustrated. Note the evident toughness of the metal even in the raw condition. The diameter of the rolls of metal shown is from 1.5 to 2 inches.

Acid Practice Data in General

The Addition of Alloys

This practice varies so in different shops that it is rather difficult to lay down any set rule. The writer has found that on the general run of heats, superior results are to be obtained by bringing the metal to a high temperature under a perfect slag, adding the manganese in moistened lumps, exactly 3 minutes before tapping. The silicon is added to the ladle in wheat size, being thrown in directly under the stream when the ladle is about half full. The steel is then held in the ladle from five to ten minutes before the first mold is poured, bottom pour ladles being exclusively used.

There is one point in respect to the pouring of castings which requires mentioning, that of segregation of silicon in the latter part of the pour. A very hot heat of steel being poured over a period of say, 30 minutes, is naturally in contact with a considerable area of very hot slag. It is but natural that at this junction of steel and slag, there should be a certain amount of reduction progressing. This results in a very thin layer of metal directly under the slag covering which is gradually increasing its silicon content. As the heat nears the end of the pour this ring of metal approaches the bottom of the ladle, and is finally poured into the last mold. Fig. 9 shows the result of a casting poured from this final metal. Photo 3 is the last mold; photo 2 next to last; and photo 1 second to last. The molds poured were those containing center plates, each taking approximately 75 pounds of metal. Nos. 1 and 2 show a perfect fracture, while No. 3 shows extreme segregation of silicon. This final casting when dropped

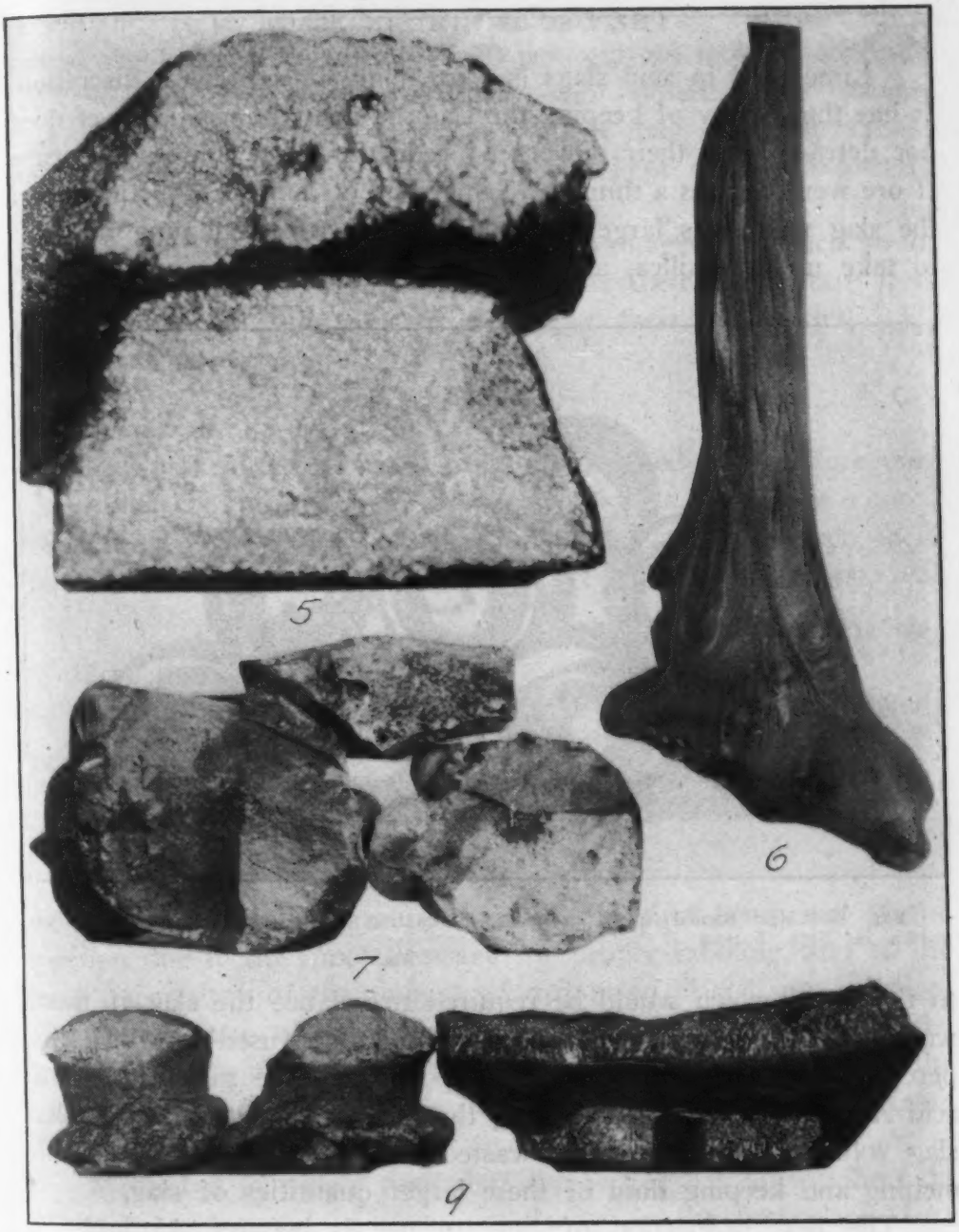


Fig. 5—Showing a fracture of perfectly sound material. Fig. 6 and 7—The appearance of perfect slags. Fig. 9—Shows the result of a casting poured from the later part of the heat wherein the silicon has segregated.

on the floor broke in three pieces. To avoid any possible trouble from this source, low grade castings should be poured with the last few hundred pounds of metal, so that if segregation occurs, the loss will be small.

The Use of Lime in Slags

Lime used in acid slags is a great aid if used with discretion. It has the faculty of keeping the slags in a fluid condition, yet does not detract from their powers of reduction as would be the case if ore were used as a thinner. Lime prevents silicon reduction when the slag volume is large, and tends to offer a combining material to take up free silica, allowing considerable manganese to return

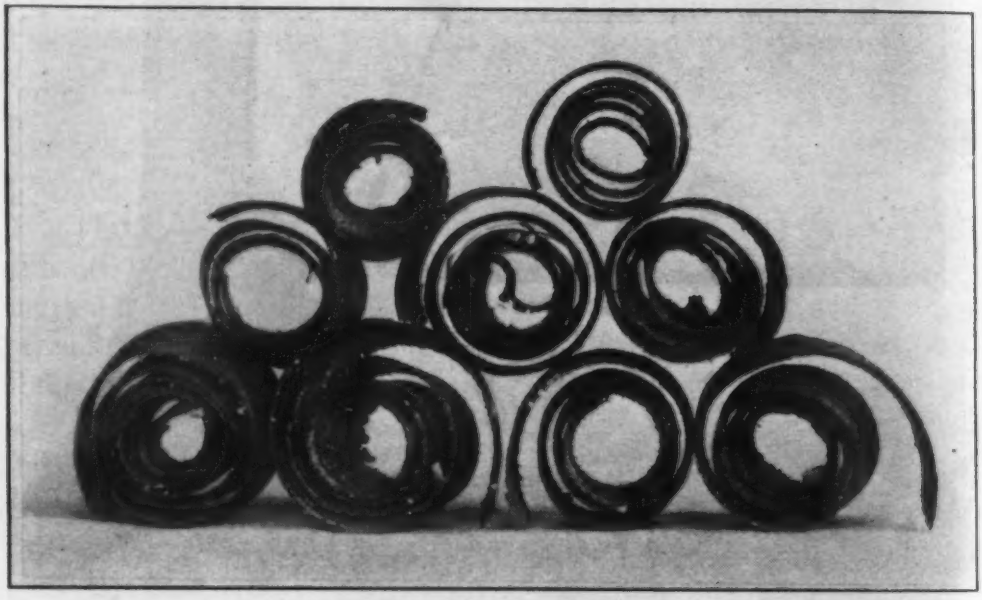


Fig. 8—Chips turned from an annealed casting poured under slag conditions shown in Figs. 6 and 7.

to the metal which would be required to balance the slag if there were no lime present. This allows slags to be used in which the percentage of oxides is low in proportion to the general run of acid slags, and aids in deoxidizing the metal efficiently with smaller slag volume, resulting in less wasted heat and power used in the melting and keeping fluid of these larger quantities of slag.

The best proportion of lime to use is between 15 and 25 per cent with 30 per cent as the absolute limit, any amount above this point having the tendency of corroding the walls. This lime is best added with the ordinary slag, the silica sand and lime being mixed. Small chips of marble or limestone are excellent materials to use, and oyster shells have been used by the writer with favorable results. On heats where much machineable work is to be poured, or where alloy steels, such as high manganese, nickel

or chrome, is to be used, it is excellent practice to make up a special slag mixture consisting of 70 per cent old molding sand, 25 per cent lime and 5 per cent crushed coke. Where higher carbons than ordinary are desired the coke content may be safely raised, the proportions of silica to lime being kept at approximately 3 to 1.

Coke and lime both offer distinct advantages, as much so in the acid process as in the basic, and while their use is rare it is well worth the melter's time to investigate their possibilities.

Recarbonizing

This procedure has been briefly mentioned in the foregoing pages, but this subject is of such importance as to require a more detailed explanation. Under conditions of present practice there are several methods of attaining this desired increase in carbon:

1. By the use of coke, coal, or other carbonaceous material thrown into the furnace.
2. By the use of special carbon-containing compounds such as "carburite," etc.
3. By immersing the carbon electrodes into the metal with the power off.
4. By the use of pig iron.

Methods 1 and 2 are rarely used, the first being out of the question due to the time necessary for proper rabbling, and to the great uncertainty of the amount of carbon so placed into solution. The second item offers carbon in a concentrated form, with the large possibility of pieces of this material floating on the slag, the consequent result being a wide difference in the actual carbon from that calculated.

Method 3 is widely used, but the writer has always been at a loss to understand its great popularity. In the first place there is the high cost, electrodes at 7 or 8 cents a pound being a very high priced recarbonizing material. In the second place there is the extremely hazardous feature of uncertainty, the usual method being to immerse the electrodes immediately before the pour for a certain specified length of time, then pour blind. While the writer agrees that the addition of carbon at this time offers certain advantages, he fails to see where this process can be in any manner exact,

due to the many variables. Such items as changes in temperature of the metal; the composition of the metal itself; the character of the slag, the exposed area of the electrodes; the depth of immersion; the composition of the electrodes, etc., are always different, and this method at the best must be but a close approximation.

The use of pig iron has caused much heated discussion. Adherents of the other methods have certain arguments, the main ones being its reputed cost, and the great danger of the lowering of the carbon content caused by robbing the metal of this element, to reduce silicon. The first objection is partly true, that the use of pig iron slightly raises the cost of the metal, but as its use insures higher quality, and more regular analyses, this added cost is an asset and can be taken as a measure of the shop's standard of quality. The second objection, while given much space in the technical press as a fact, is absolutely erroneous. The writer has yet to see the heat of low or medium carbon steel where the silicon was reduced at the expense of the carbon content of the metal. He has seen many heats where the silicon was increased 0.20 to 0.30 per cent in a few minutes, but careful checks showed that during this time the carbon dropped only 0.03 per cent. In the light of chemical fact, if the carbon actually reduced the silicon according to the equation: $SiO_2 + 2C = Si + 2CO$ the carbon must have of necessity dropped more than the silicon increased, a point which did not happen.

The use of pig iron offers such great advantages that its use should be accepted as standard. A great deal, of course, depends upon the manner in which this pig iron is added. The practice which the writer has adopted, and advocates is as follows:

As soon as the heat is nearly melted a metal test is taken for carbon. If the carbon is high enough, so that no great increase, outside of the natural ones from ferromanganese, etc., are required, the heat is finished by the general procedure. If, however, the test shows unusually low carbon the bath should be given a good dusting of crushed coke, and the final slag added. Metal tests taken every few minutes will show the manner in which reduction in proceeding. If the metal begins to warm up with the slag still remaining in an oxidized condition, about 100 pounds of pig iron should be added for a three-ton heat. A metal test taken in five minutes will show the result of this addition. This

should be repeated until the composition of the metal is at the desired point, at which time the metal is usually ready to add the alloys and pour.

Not only does this pig iron addition raise the carbon content of the metal, but it acts as a deoxidizing agent, and materially lowers the time necessary to bring a bad slag to the proper pouring condition.

Temperature Testing

The judgment of pouring temperatures is very important, if high grade results are to be obtained. Cold metal results in needles, sculls and pigged metal, while very hot steel gives rise to scabbing and rough appearing castings, increasing the cleaning cost. Heats should be so arranged that either a heat of hot or cold metal can be poured. This is an advantage, in that the large and complicated castings can be poured with cold metal, while those of thin section or small size, can be poured from the hot heat, the metal chilling so fast on these latter pieces that cutting of the mold is kept to a minimum.

There are several methods of judging the temperature of a heat of steel:

1. By use of an optical pyrometer.
2. By the time test.
3. By the rod test.
4. By the lip pour test.

The optical pyrometer finds small use due to the inability of obtaining correct "black body" conditions together with the inaccuracies of its manipulation. It finds its widest use in determining the temperature of the stream pouring from the spout or from the ladle and thus is a help in determining the temperature of the metal as the pouring of the molds proceeds.

The time test is widely used and consists in taking a spoon full of metal from the furnace, skimming its surface free from slag, and noting the number of seconds it requires for the surface of the metal to skim over. The number of seconds required is taken as an indication of the temperature of the metal, and runs from 25 to 60 seconds on low carbon steels.

The rod test is made by inserting a rod of a certain size into the metal for a specified number of seconds. If the rod is burned

off clean the metal is hot; if burned off tapering the metal is of a medium temperature; while if unburned, or sculled, the metal is cold.

The lip pour test is made by taking a spoon full of metal from the furnace and noting the manner in which the steel runs over the lip of this test spoon as it is being poured into the test mold. The temperature of the metal is determined by the appearance of the stream, the scull left in the spoon, and by the appearance of the metal after the mold is filled. The writer prefers the latter. All of these tests depend entirely upon the melter's judgment. The point of importance being that every test must be taken in exactly the same manner each time, and every heat followed on the floor as a check. After a short time an operator becomes expert in determining the temperature of liquid metal, and off heats from this cause become a rarity.

Special Steels

The acid furnace is only rarely used in the production of alloy steels due to its inability to recover any of the high-priced alloys when the shop scrap is remelted. There are, however, certain classes of steels which are being made in the acid furnace, as side lines, by shops operating such furnaces.

The manufacture of these steels requires no difficult manipulation, the greatest point being that a little more care is required than when working on carbon steels. Each heat should be brought to a perfect finishing condition, when the alloys desired are added a certain allowed time before the pour.

Nickel Steels

Nickel scrap can be remelted in the acid furnace with only a slight loss, no changes being required from the operations as practiced on the carbon mixes. On heats where an addition of this element is necessary it can best be added directly with the charge as the pig nickel, and can be figured in a quantitative manner. The fracture tests on steels with over 2.00 per cent nickel will have a changed appearance from the carbon steel fractures, and unless the melter is acquainted with this peculiarity the services of a chemist will be necessary for the preliminary tests.

Chromium Steels

Remelted chrome steel entails a complete loss of this alloy. Any steel requiring chromium will, therefore, require that this alloy be added just before the pour in order that the oxidation loss be kept to a minimum. Chromium should be added at the end of the heat along with the manganese, allowing from 3 to 5 minutes before the pour, depending upon the percentage used. It should be added in moistened lumps, and should never be added to the ladle.

Manganese Steels

This metal can not be remelted in the acid furnace except in small amounts, as manganese has a great affinity for an acid hearth and lining, rapidly eating it away to form a balanced slag. The general method of making this steel from the acid furnace is to finish a heat of low carbon steel, heat it to a very high temperature, and as the heat is tapped, molten ferromanganese is added to the ladle. This ladle is allowed to stand for several minutes until diffusion is complete, when the molds can be poured. The ferromanganese is either premelted in crucibles, or in a small cupola if regularly used.

Vanadium Steels

The best method of adding vanadium is to thoroughly pulverize the ferroalloy, and add this powder to the stream as it pours over the furnace spout. As vanadium is added only in small amounts this method assures complete solution, and absolute melting of this high-priced alloy. Vanadium in steel scrap can never be reclaimed in the acid furnace.

High Carbon Steels

Heats of this class of metal are best made by charging a grade of high carbon steel which on the melt down will have an analysis close to that desired. Heats made in this manner require only a small amount of pigging to bring back and result in cheaper and better operating figures. A chemist should always be used on heats where the carbon is higher than 0.50 per cent as the ability to read the fractures on the higher carbon contents becomes more difficult as they increase.

Final Deoxidizers

These powerful deoxidizing alloys are widely used and confer certain desirable assets to a heat of steel. In general they consist of those alloys which have a powerful affinity for oxygen in any form. These metals are principally aluminum, calcium, magnesium, silicon, manganese, titanium, vanadium, uranium, and zirconium and are used, either singly or in combination.

The writer once favored the use of aluminum in small amounts but he has since seen the fallacy of such recommendation, and is now strongly opposed to the use of this metal. The greatest point against the use of aluminum is that in good heats it is not needed, as it only increases the shrinkage of the metal to such a degree that considerable trouble is caused the shop in welding up shrink holes, and repairing cracked castings due to the heavier shrinkage.

Vanadium, titanium and uranium offer characteristics which make their use desirable, having the ability of not only cleansing the steel from oxygen, but being able to eliminate nitrogen, an element as derogatory in its action as oxygen. The last mentioned alloying-element is not widely used, but the two former ones have widely increased in their application.

Of all final deoxidizers these two, vanadium and titanium, are the only ones the writer recommends. They both increase the quality of the steel wherever used, regardless of the care used in its manufacture. As they constitute an added cost, their use should naturally be restricted to heats where a metal of exceptional quality is desired.

INTERCRYSTALLINE FRACTURE IN STEEL

By R. S. Williams and V. O. Homerberg

Abstract

This paper discusses an abnormal type of failure in mild steel characterized by intercrystalline cracking and produced by the action of cathodic hydrogen or caustic soda solutions. The effect of hydrogen on steel under tension is shown and also the action of alkaline solutions on inclusions of known chemical composition artificially introduced.

Introduction

THE continued use of natural or treated waters containing sodium carbonate often leads to an abnormal type of failure in boiler steel. These failures are characterized by the appearance of intercrystalline cracks in the riveted joint areas. In the course of an extended investigation of failures of this kind, carried out at the suggestion of the Babcock & Wilcox Co. and with their continuous co-operation, certain results have been obtained which seem to be of sufficient importance to justify advance publication before the investigation is completed.

The fact that mild steel is made distinctly brittle under the influence of cathodic hydrogen has been known for some time.

Methods, Apparatus and Procedure

The actual effect of cathodic hydrogen on mild steel is strikingly shown in an experiment carried out with a flat tensile test bar, the dimensions of which are given in Fig. 1. A study was made in the rate of penetration of cathodic hydrogen on this test bar, first when clamped in a tensile testing machine without load, and second, as increasing loads were applied until the yield point was passed. The effects on the microstructure were also noted.

Acknowledgement is made to Messrs. Zavarine and Yarotsky for assistance given and especial thanks are due Prof. C. L. Norton, of the Massachusetts Institute of Technology, for his interest and co-operation.

A paper presented before Boston chapter of the Society. The authors, Dr. R. S. Williams and V. O. Homerberg are respectively associate professor and instructor in metallography and Babcock and Wilcox Fellows at the Massachusetts Institute of Technology.

The apparatus that was used is shown in Fig. 1a and was designed by A. Ortiz and modified by Dr. C. Nusbaum. The receptacle at the left contains a 4 per cent solution of caustic soda. The glass vessel at the right side of the tensile test bar contains distilled water. The caustic solution and the distilled water were

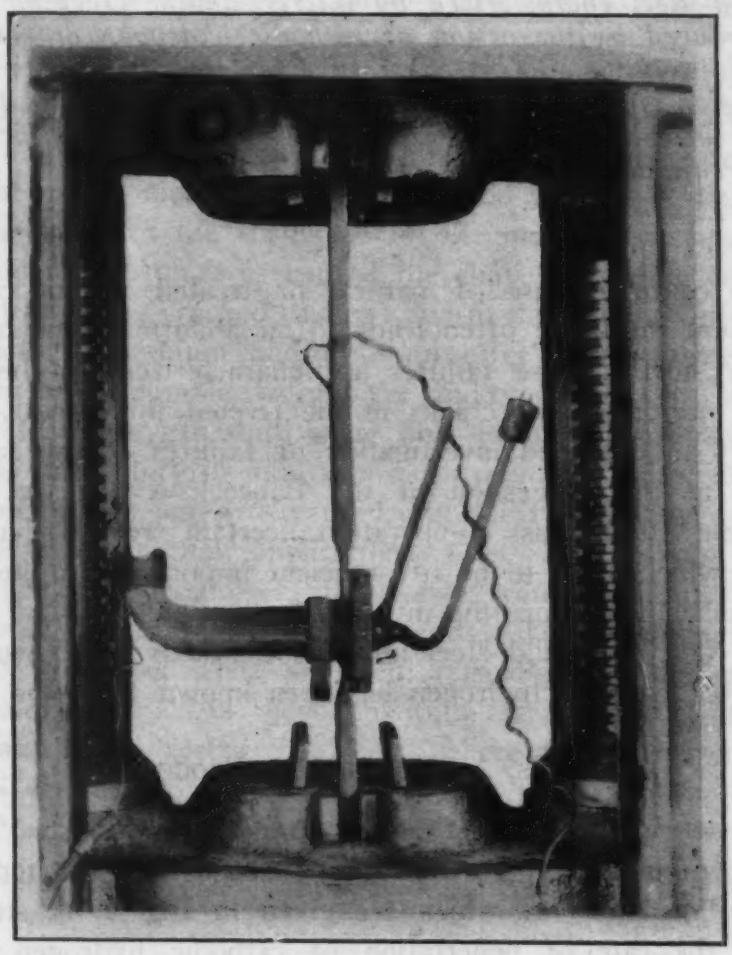


Fig. 1a—Photopragh of apparatus and testing equipment used in the study of hydrogen penetration.

both protected from carbon dioxide from the air by means of U tubes (not shown in the figure) which were filled with soda lime. The quantity of the caustic solution was accurately measured. The test bar was made the cathode and a platinum wire the anode.

The study of the penetration extended over a period of about one month during which time readings were taken at regular intervals, before the test bar was loaded, while loaded below the

yield point, while loaded at the yield point, and finally while loaded above the yield point. The specimen was finally broken and sections prepared for microscopic examination.

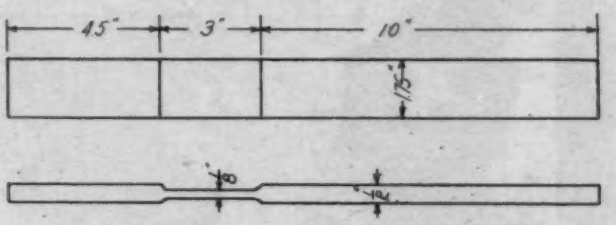


Fig. 1—Sketch of test bar used in making these tests.

The difference in the rate of penetration of the test bar when in the unstrained and in the strained condition was quite marked. Stressing beyond the yield point did not appear to have any further effect on the rate of penetration.

Observations

Several interesting observations were made. A black deposit formed on both sides of the test bar. Also, rather large masses of black material were obtained on the distilled water side. Furthermore, the distilled water had a strong odor of hydrogen sulphide when the apparatus was disconnected. Chemical tests indicated that the deposit was probably iron sulphide.

The specimen broke with a dull sound. A number of blisters had formed on the side of the caustic solution and in the direction of rolling of the material. These blisters on polishing for microscopic examination showed crescent-shaped cavities as shown in the photomacrograph, Fig. 2 and the photomicrograph, Fig. 3. Intercrystalline cracks are shown in photomicrographs, Figs. 4 and 5. A crack, which developed from one terminus of a blister, is shown in photomicrograph, Fig. 6. Partially and completely altered slag areas are shown in Figs. 7, 8 and 9.

Hydrogen Penetration Greatest Above Yield Point

A similar experiment was made on a second bar. The action of cathodic hydrogen extended over a period of several

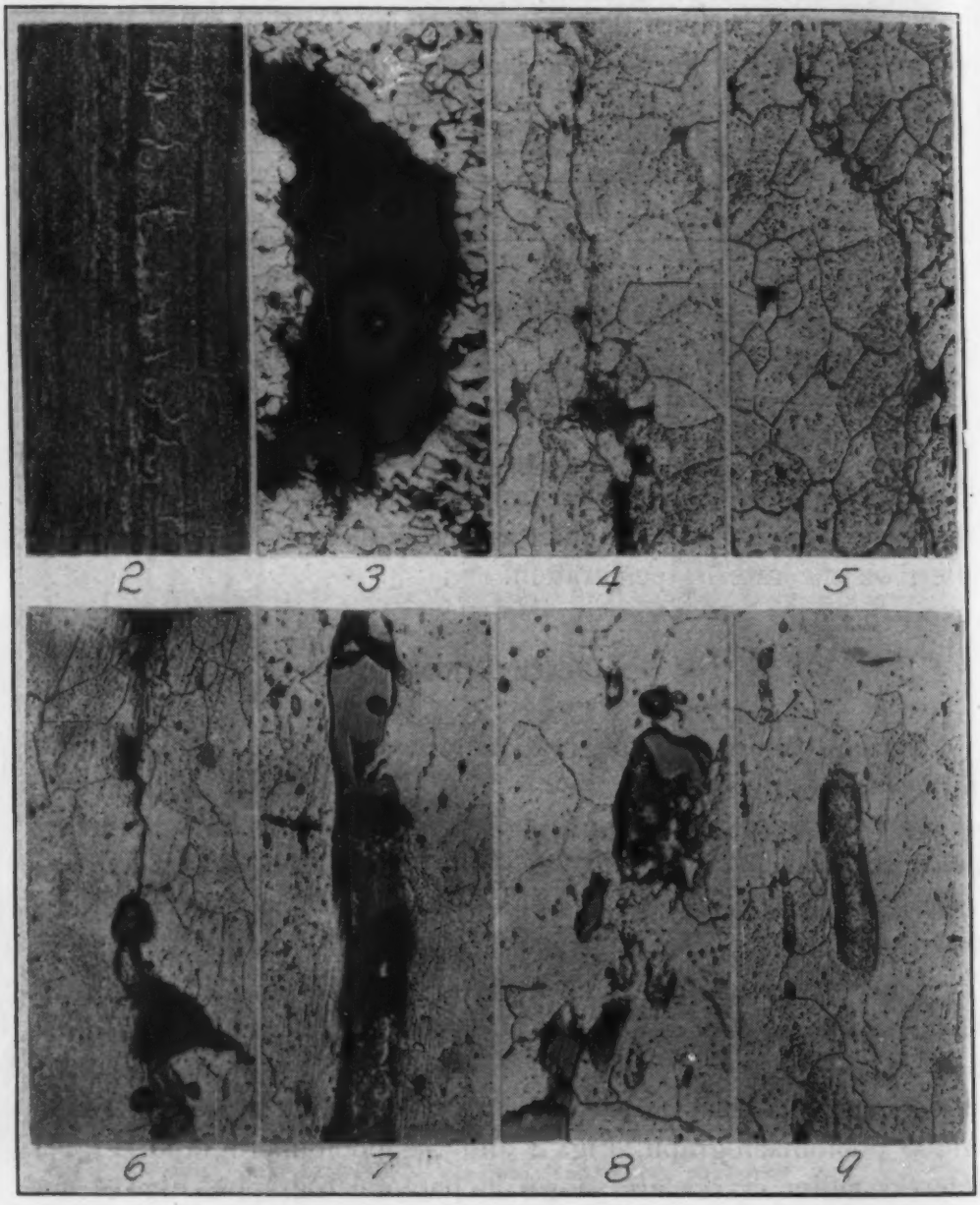


Fig. 2—Macrograph of blister cavities. 3X. Fig. 3—Photomicrograph of blister section. Nital. 75X. Figs. 4, 5 and 6—Intercrystalline cracks in test bar. Nital. 250X. Figs 7, 8 and 9—Partially and completely altered slag inclusions. Nital. Figs. 7 and 9, 250X. Fig. 8, 500X.

weeks during which time the stress on the specimen was gradually increased. The specimen was removed from the holder after the yield point had been passed, and prepared for microscopic examination. Again, partly and completely decomposed slag in-

closures and many intercrystalline cracks were visible. The rate of penetration of the hydrogen through the steel increased as the tensile stress was increased, reaching a maximum with the passing of the yield point. In each instance, immediately after the stress was applied, the rate of penetration markedly decreased. This de-

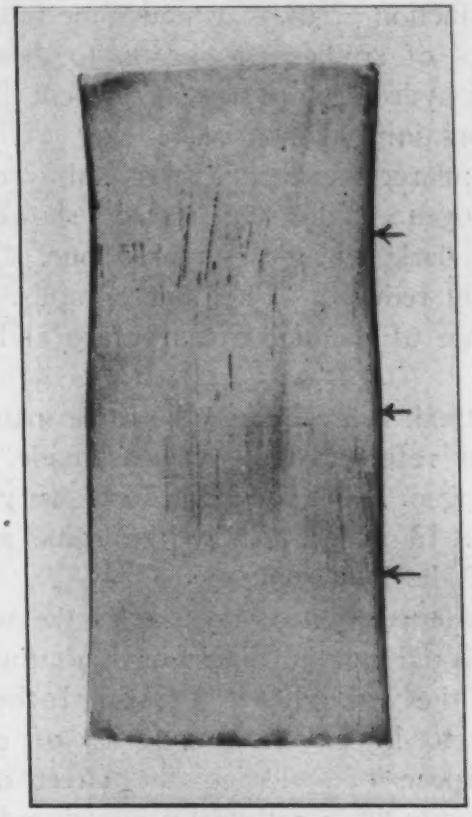


Fig. 10—Test bar stressed above yield point under action of hydrogen. Shows contraction at two points. 1X.

crease was especially marked immediately after the yield point was passed. Hydrogen sulphide was again detected in the distilled water thereby suggesting the possibility of the reaction of the sulphide in the steel with the penetrating hydrogen. This conclusion is not positive, however, since sulphur was found in the gutta percha gaskets with which the specimen was held tightly in contact with the glass receptacles.

A marked effect of the action of cathodic hydrogen was noticed as the breaking load was approached. A necking occurred

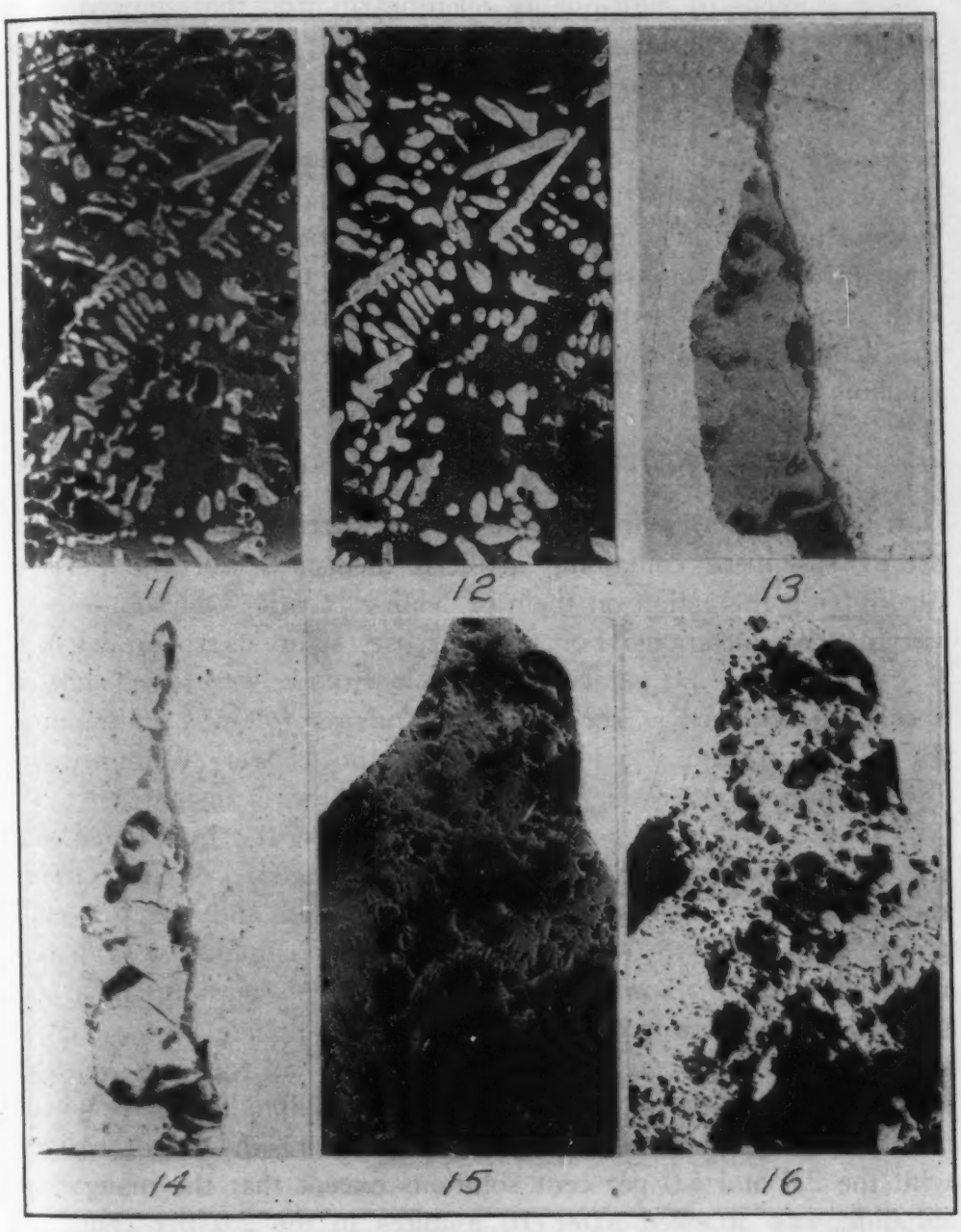
at points just outside of the part exposed to the action. The contrast in the ductility of the affected and unaffected parts is shown in Fig. 10.

Effect of Cathodic Hydrogen on Slag Inclusions

Many bits of evidence in this and earlier experiments indicated an actual reduction of the slag under the influence of cathodic hydrogen. A series of studies was begun to determine the actual effect of cathodic hydrogen on slag as present in iron and steel. Wrought iron containing considerable slag of the duplex type (containing two microconstituents) was subjected to the action of cathodic hydrogen. The slag masses showed a bluish-gray constituent and a darker or dove-colored one. The lighter constituent was readily reduced. Photomicrographs, Figs. 11 and 12 show the appearance of the slag areas before and after the action respectively.

A long slag streak in mild steel, the same material from which the tensile test bar referred to above was made, was acted upon by cathodic hydrogen. The reduction was very rapid. Photomicrographs, Figs. 13 and 14 show the same areas before and after the action of the hydrogen.

The chemical composition of the slag in the wrought iron and in the mild steel could not be determined accurately, and as the experiments with the wrought iron showed the action of the cathodic hydrogen to be selective, a series of experiments was made for the purpose of studying the effect on inclusions of definitely known composition artificially introduced into mild steel. Holes 3/16 inch in diameter were drilled into sections of mild steel, 2½ inches in diameter. Each piece was packed with one of the following materials: iron sulphide (FeS), manganese sulphide (MnS), iron oxide (FeO) and manganese oxide (MnO). The holes were then closed and the pieces forged to ½-inch square bars. Sections approximately 3/8 inch in thickness were cut from each bar, photographed and then subjected to the action of cathodic hydrogen. Photomicrographs, Figs. 15 and 16 show the same area before and after the action on iron oxide (FeO). The black areas in each case indicate cavities. In Fig. 17 the dotted line indicates the demarcation between the reduced and the unreduced parts of the iron oxide as found in the longitudinal section. The mangan-



Figs. 11 and 12—Slag in wrought iron before and after action of cathodic hydrogen. Unetched. 250X. Figs. 13 and 14—Slag in mild steel before and after action of cathodic hydrogen. Unetched. 100X. Figs. 15 and 16—Artificially included iron oxide before and after action of cathodic hydrogen. Unetched. 100X.

ese oxide was much more slowly reduced. The iron sulphide was acted upon but slightly while the manganese sulphide was attacked somewhat less readily than the iron sulphide.

Specimens of high quality open-hearth iron that showed small round inclusions, bluish in color, probably manganese sulphide, flesh colored spots of iron sulphide and large irregular masses also bluish in color, probably iron oxide, were subjected to the action of cathodic hydrogen. The irregular bluish masses were completely reduced whereas the rounded and flesh-colored masses remained practically unattacked. The addition of antimony-potassium tartrate in acid solution, to the polished surface of the specimen caused the formation of yellowish-brown halos, confirming the belief that the rounded and the flesh-colored inclusions were sulphides.

Caustic Soda Test on Synthetic Slag Inclusions

The next series of experiments was carried out with a similar set of specimens containing artificial inclusions, for the purpose of studying the action on them of boiling caustic soda solutions of varying concentrations. For this purpose, solutions containing 0.1, 0.5, 1.0, 2.0 and 5.0 per cent sodium hydroxide were used and the specimens removed at successive intervals as follows: 10 minutes, 30 minutes, 1, 2 and 5 hours. All specimens were examined before boiling to determine the condition of the inclusions.

In the 0.1 per cent caustic soda solution the iron oxide and the manganese oxide were intact after 5 hours. After 2 hours the manganese sulphide became slightly pitted and the iron sulphide was completely removed. The iron sulphide was partly removed after 10 minutes. In the 0.5 per cent solution similar results were obtained except that the iron sulphide was removed after 1 hour. The oxides remained intact in the 1.0 per cent solution. After 10 minutes the manganese sulphide became pitted and the iron sulphide was removed. Similar results were obtained with the 2.0 and 5.0 per cent solutions except that the manganese sulphide was attacked after 10 minutes in the 2.0 per cent and completely removed after 10 minutes in the 5.0 per cent solution.

A study of the action of a boiling 2.0 per cent solution of caustic soda on pure iron containing varying proportions of iron and manganese sulphides, was made. Iron sulphide was added to electrolytic iron, previously melted in a crucible made from zirconium oxide in order to avoid contamination of the melt with other impurities. Photomicrographs, Figs. 18, 19 and 20 show the

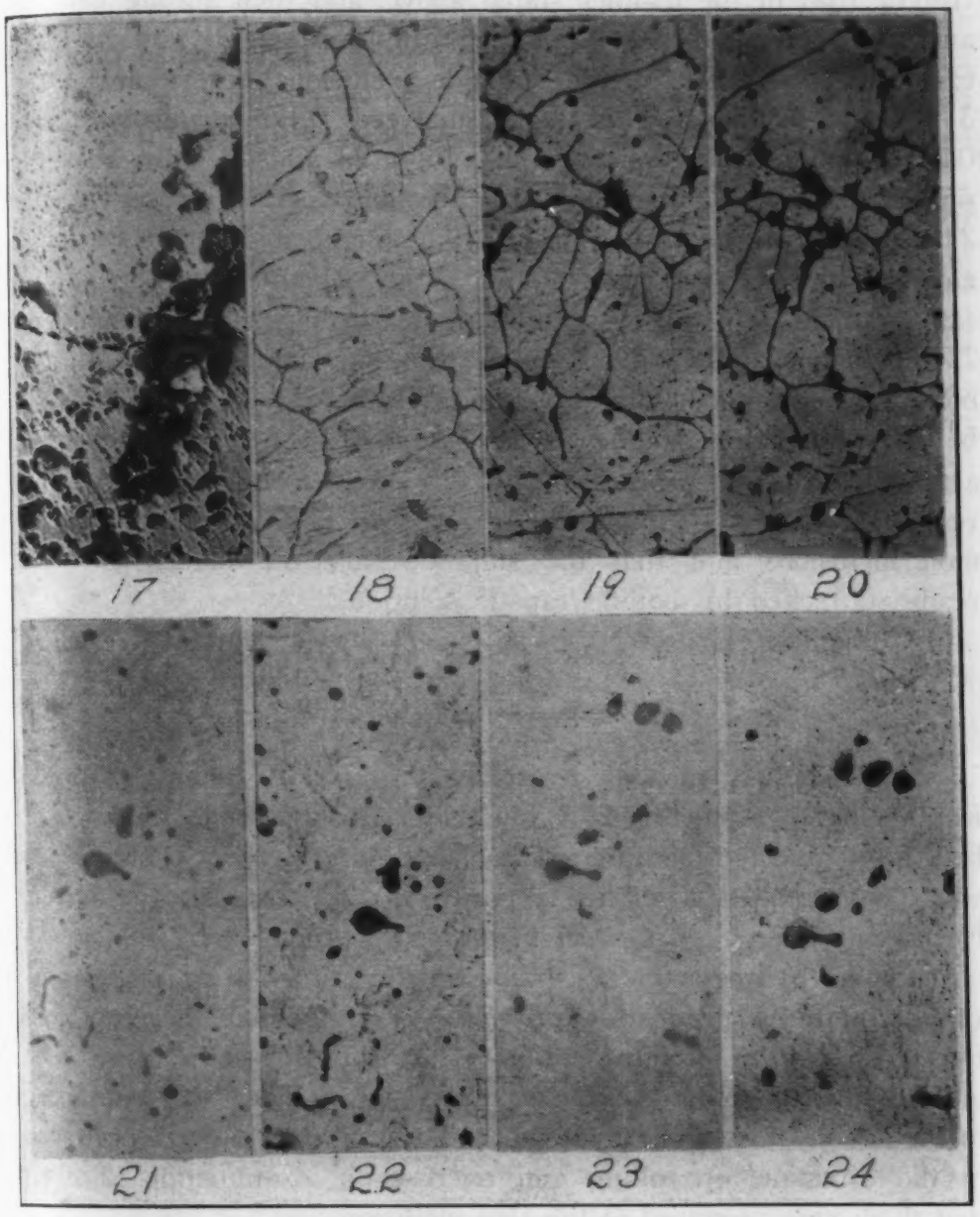


Fig. 17—Dotted line shows boundary between reduced and unreduced iron oxide. Fig. 18—FeS, artificially introduced. Unetched. 250X. Figs. 19 and 20—Steel shown in Fig. 18 following action of boiling caustic for 2 hours and 10 hours respectively. Not repolished. Figs. 21 and 22—Sulphide inclusions before and after action of boiling caustic. Unetched. 500X. Figs. 23 and 24—Similar to Figs. 21 and 22.

network of iron sulphide (FeS), Fig. 18 that of the unattacked specimen, Figs. 19 and 20 after exposure for 2 and 10 hours respectively. The iron sulphide was completely removed.

Several ingots were prepared by adding iron sulphide to elec-

trolytic iron in the manner stated above, and then adding varying amounts of manganese. Photomicrographs, Figs. 21 and 22 indicate the appearance of the sulphide inclusions before and after 3½ hours boiling. This ingot analyzed 0.179 manganese and 0.265 sulphur. Photomicrographs, Figs. 23 and 24 show the sulphide inclusions before and after boiling for 5 minutes in the 2.0 per cent caustic soda solution. This ingot analyzed 0.636 manganese and 0.362 per cent sulphur. Figs. 25 and 26 are from the same sample. A third specimen from an ingot which analyzed 2.73 manganese and 0.195 sulphur, was similarly treated with the boiling caustic soda solution. Figs. 27 and 28 show the results before and after boiling for 5 minutes. The experiments on artificial inclusions show conclusively that iron oxide is more readily attacked by cathodic hydrogen than any other of the common inclusions and that the sulphides are the inclusions most readily attacked by boiling caustic solutions.

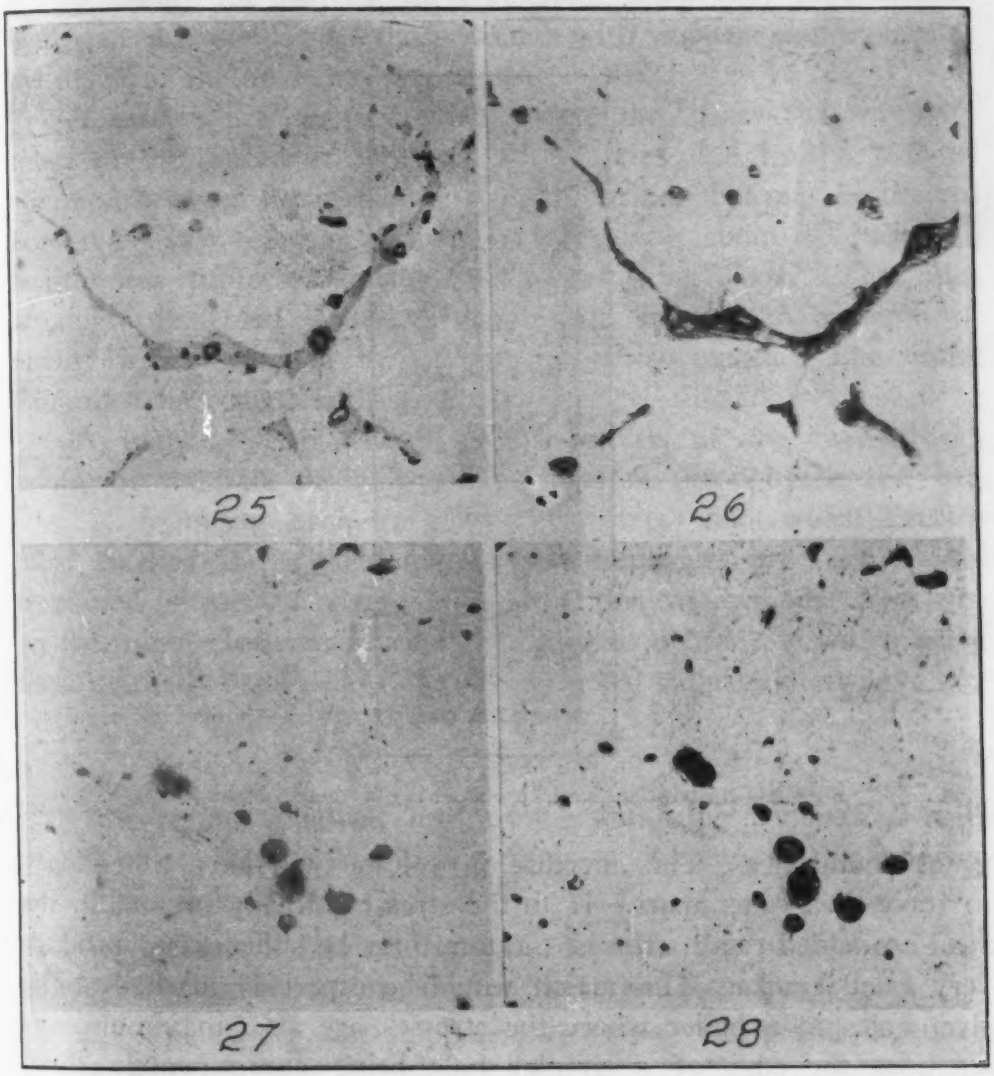
Hydrogen Tests on Oxides

The action of cathodic hydrogen on oxides is strikingly shown in photomacrograph, Fig. 29. The material is Bessemer steel which had been rejected because of too high an oxygen content. It was photographed after its exposure to the action of cathodic hydrogen. The blisters were undoubtedly produced by the action of cathodic hydrogen on the oxide as the reduction of iron oxide (FeO) and the production of water is undoubtedy accompanied by an increase in volume. Blisters of this character were first observed with wrought iron specimens, which had been subjected to the action of cathodic hydrogen. These blisters always occurred in the direction of rolling and microscopic examination showed that they were produced at the slag inclusions.

Boiler Plate Material Under Investigation

A study was undertaken of actual boiler plate from boilers that had failed in service, the analyses of which came within specifications in each case. These failures generally occurred in cases where the water supply showed considerable alkalinity. These results will be published in the near future.

The facts described above, i. e., the reduction of oxides by cathodic hydrogen and the removal of sulphides by caustic soda solutions lead directly to an understanding of two of the factors involved in the intercrystalline cracking in steel. As molten steel



Figs. 25 and 26—Sulphide inclusions before and after action of boiling caustic. Unetched. 500X. Figs. 27 and 28—Similar to Figs. 25 and 26. Figs. 22, 24, 26 and 28 were not repolished after the caustic treatment.

solidifies the impurities are to a great extent rejected to the grain boundaries so that much of the iron oxide and any iron sulphide that may be present would be found in places where their removal would tend most strongly toward a weakening at the boundaries. This effect would be aggravated if the steel were under tension as

is general in the case of boiler plates and in rivets. Wherever tension exists, very small capillaries must be formed as a result of the lack of adhesion between the inclusion and the metal itself. The cathodic hydrogen would produce water as the result of the reduction of iron oxide and cause an increase in volume at the

Fig. 29—Blisters on steel, produced by cathodic hydrogen. ¾-X.

grain boundaries. This increase in volume will have a tendency to force the grains apart. If to the stresses already present in the steel are added these stresses, the total may be sufficient to produce very small cracks. This action would be especially marked at the rivet holes in a boiler where the stresses are at a maximum, the stress at the edge of a circular hole being approximately three times the average stress.

Moore and Beckinsale[1] have shown that when copper, containing the copper-copper oxide eutectic at the grain boundaries, is annealed in a reducing atmosphere, intercrystalline cracks will be produced due to the reduction of the copper oxide. The resulting water vapor exerts sufficient force to produce a separation of the grains. It was shown that copper free from oxide will not

1. Journal Institute of Metals No. 1, 1921, Vol. XXV.

behave in this manner. Since it has been shown that cathodic hydrogen will give at room temperature, results which require an annealing temperature when molecular hydrogen is used, it is probable that the effects produced on iron at boiler temperatures, approximately 200 degrees Cent., (392 degrees Fahr.) with cathodic hydrogen are similar to those found with copper and molecular hydrogen at the annealing temperature.

A case, which seems to substantiate the theory that capillary tubes are produced at the grain boundaries due to the lack of adhesion between the matrix and any impurities that may be present occurred when a large piece of brass tubing about 10 inches in length was subjected to the "season cracking" test. The tube, although immersed in mercurous nitrate solution to a depth of about 1 inch, cracked throughout its entire length. The entire fracture was coated with mercury.

A tentative explanation may be given of the marked decrease of the rate of hydrogen penetration through the test bar, Fig. 1, following each application of stress and which became most marked at the yield point. The capillaries produced by the combined effects of stress and the action of cathodic hydrogen on the minute inclusions become filled with debris, the action being most marked at the yield point where actual slippage occurs.

Conclusions

The results obtained lead to the following conclusions with regard to the intercrystalline cracking of steel under the influence of caustic solutions:

1. During the crystallization of steel, the impurities, to a considerable extent, are rejected to the grain boundaries.

2. The oxides and sulphides are two of the prime factors in caustic embrittlement.

3. The oxides are reduced under the influence of cathodic hydrogen.

4. The sulphides are removed due to the action of hot caustic soda solutions.

5. The removal of the sulphides produces a surface condition favorable to progressive corrosion.

6. Assuming that progressive corrosion starts with the re-

moval of the sulphides, the corrosion will be greatly accelerated if the material is stressed. Furthermore, when the steel is under tension there is a tendency for the matrix to pull away from the inclusions at the grain boundaries and in this manner to produce small capillaries into which the corroding solution can penetrate.

7. In stressed areas containing oxides, the volume increase due to the reaction with cathodic hydrogen, may produce stresses which added to those initially present, may cause cracking.

8. It seems evident that hydrogen acts in three ways to produce embrittlement; first, the temporary brittleness caused by absorbed hydrogen (as in acid pickling), second, it acts to reduce oxides, and third, its effect due to the change in volume at the grain boundaries, resulting because of the production of water. This latter volume increase would create a stress which, added to those originally present, may cause cracking, especially at those points where these stresses are at a maximum.

TRANSPARENT METALLOGRAPHY

By L. V. Foster

Abstract

A method of preparing transparent specimens of polished and etched metal surfaces is described. The specimen which has been freshly prepared is coated with a thin layer of collodion, which, when dry, is stripped from the cast and mounted on a micro glass slide and protected by covering with the usual micro cover glass. This celluloid strip or replica has imprinted on it the exact structure which the etching has brought out on the surface of the metal specimen. It can be examined on the ordinary table microscope using either transparent bright field illumination or dark field illumination, the latter producing negative representation.

A specimen containing the finest structure prepared in this way and observed by means of dark field illumination renders visible all detail present in the metal specimen.

Introduction

THE earliest work in metallography which we have reference to, was first begun by Sorby in 1863. In 1849, he prepared the first rock slice ever made, and his early microscopical study of igneous rocks led him to prepare sections of meteorites, and later iron and steel, for microscopical examination. However, he soon found that the method used to study rock sections, failed when applied to metals, because, even in the thinnest sections possible to prepare, they were not transparent. He then discovered that by suitably etching a perfectly polished plane surface of the metal, the structure was revealed when examined under a microscope. This examination required illumination from above the specimen, which he accomplished by partially surrounding the objective with a parabolic reflector and placing in front a source of illumination which would be reflected upon the specimen. Today we have microscopes specially designed for illuminating and examining opaque objects. In most cases this is accomplished by

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A paper presented at the fifth annual convention of the Society, Pittsburgh, Oct. 8-12, 1923. The author, Leon V. Foster, is a member of the scientific bureau of the Bausch & Lomb Optical Co., Rochester, N. Y.

illuminating the specimen through the microscope objective, which is used also for observing its structure. The objective, therefore, has a two-fold function, namely, condenser and objective.

Use of Biological Microscope for Metallography

The thought occurred to the writer that it might be possible to prepare replicas of etched surfaces which could be examined on the ordinary compound biological microscope. A transparent replica, thus made, was found to display most admirably all of the structure visible in the metal sample. A primary consideration of the transparent specimen is that it can be treated like any microscope slide, using transparent illumination, either bright field or dark field. A permanent replica of any surface showing grain structure can be prepared and kept permanently. In addition to the present routine carried out in some laboratories, that of making a photomicrograph of each sample of metal, a further record can be kept of the entire specimen by the preparation of a transparent replica.

Further, the replica shows up very beautifully when studied with dark field illumination. That is, illumination brought about so that no direct light passes to the eye through the specimen. A diagram of this method of illumination is shown in Fig. 1a. The specimen is illuminated by a hollow cone of rays which are diffracted by the object causing it to be visible in the microscope. The result is, that all objects, however small, appear as bright objects, while empty space is totally black. This kind of illumination can be secured with low power objectives, that is, with 8 and 16 millimeter focus objectives by blocking out the center of the substage condenser with a dark ground stop, while with 4 millimeter and oil immersion objectives a dark field condenser is essential. (See references in footnote.) This type of illumination is not impossible on the regular metallurgical microscope but it is not entirely satisfactory and further, does not give as good results as the regular type of illumination.

Preparation of Specimen and Replica

General

The metallic specimen is polished and etched in exactly the

1. Elementary Chemical Microscopy by Chamot, 2nd edition, p. 36-47.
2. Microscopy, by E. J. Spitta, p. 172-190.
3. The Microscope, by S. H. Gage, p. 67-77.
4. The Principles of Microscopy, by Wright, Chap. XIV.

same manner as for direct examination under the microscope. The transparent replica is prepared by coating the polished and etched metal surface with collodion, allowing it to dry, then stripping off the celluloid which has impressed upon it the exact structure which was etched into the original specimen.

Technique

After the collodion has been prepared, the specimen which has been polished and etched should be carefully levelled and placed in a drying cabinet to prevent the collection of dust on

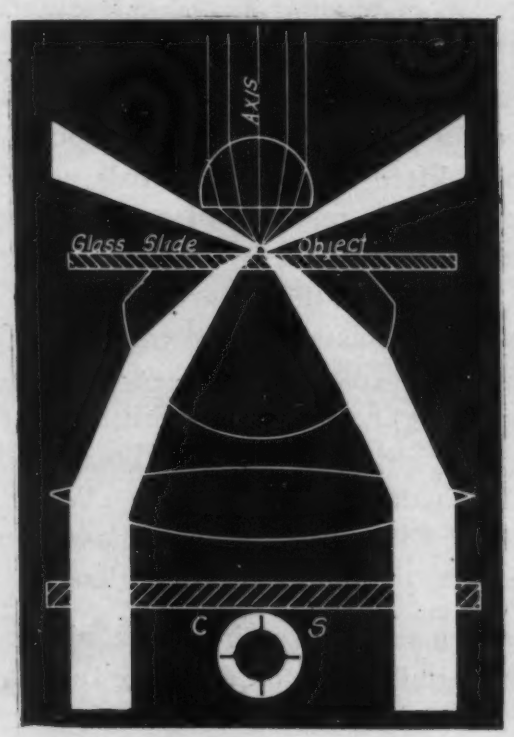

Fig. 1a—Diagram showing the transparent dark field illumination.

its surface. It should be dusted with a soft camel-hair brush and the solution flowed over the surface. The exact quantity of collodion needed to coat the specimen is a matter of experiment; too thin a film is difficult to handle while too thick a film gives a matt surface. About 0.3 cubic centimeters is the right quantity to use for a 1-inch diameter specimen. The best method of applying the solution is with a fine pipette which will hold just

the necessary quantity. This enables one to distribute the solution over the surface without touching the specimen itself and the solution can be easily led to any part, or an air bubble brought to the edge and broken.

The coated specimen should be left in the cabinet for at least 12 hours, and longer period is preferable. To strip the cast, the specimen should be placed in a dish of distilled water, when the edges will soon begin to show shadow bands. As soon as these are observed the specimen should be taken from the dish and any adherent water removed with a soft cloth. Slight pressure with the thumb nail along the edge will cause the cast to spring from the metal and should be grasped by a pair of wide jawed forceps, and pulled off with a firm but even motion. The edge of the cast should be trimmed off, and it should then be placed on a perfectly clean micro slide, which should be immersed in distilled water and lifted out with a small pool of water on its surface. One edge of the cast should be placed on the glass first, and the rest gradually brought in contact so that it pushes the water in front of it without the occurrence of air bubbles. When contact is everywhere obtained, the edges should be cemented down with some of the collodion as used for the cast. This can be applied with a very fine camel-hair brush. The cast should be cemented face up and dried by applying heat, gradually increasing the temperature to about 75 degrees Cent. When dry, the replica should be protected by mounting a cover glass over it without the use of cement between the cast and cover glass.

If replicas are made of specimens requiring low magnifications, that is, an 8 millimeter objective or one of longer focus, it is not necessary to float the cast on the slide. It can be stripped off dry and mounted dry. The slide should be ringed in asphaltum and a cover glass laid on the asphaltum ring over the replica. A little pressure on the periphery of the cover glass will fasten it quite securely, so that a second application of asphaltum on the cover glass and slide will provide a permanent mounting which can be preserved indefinitely. Any number of replicas can be made from one specimen by repeating the process.

A satisfactory collodion can be purchased from most chemical supply houses under the name of transparent lacquer.

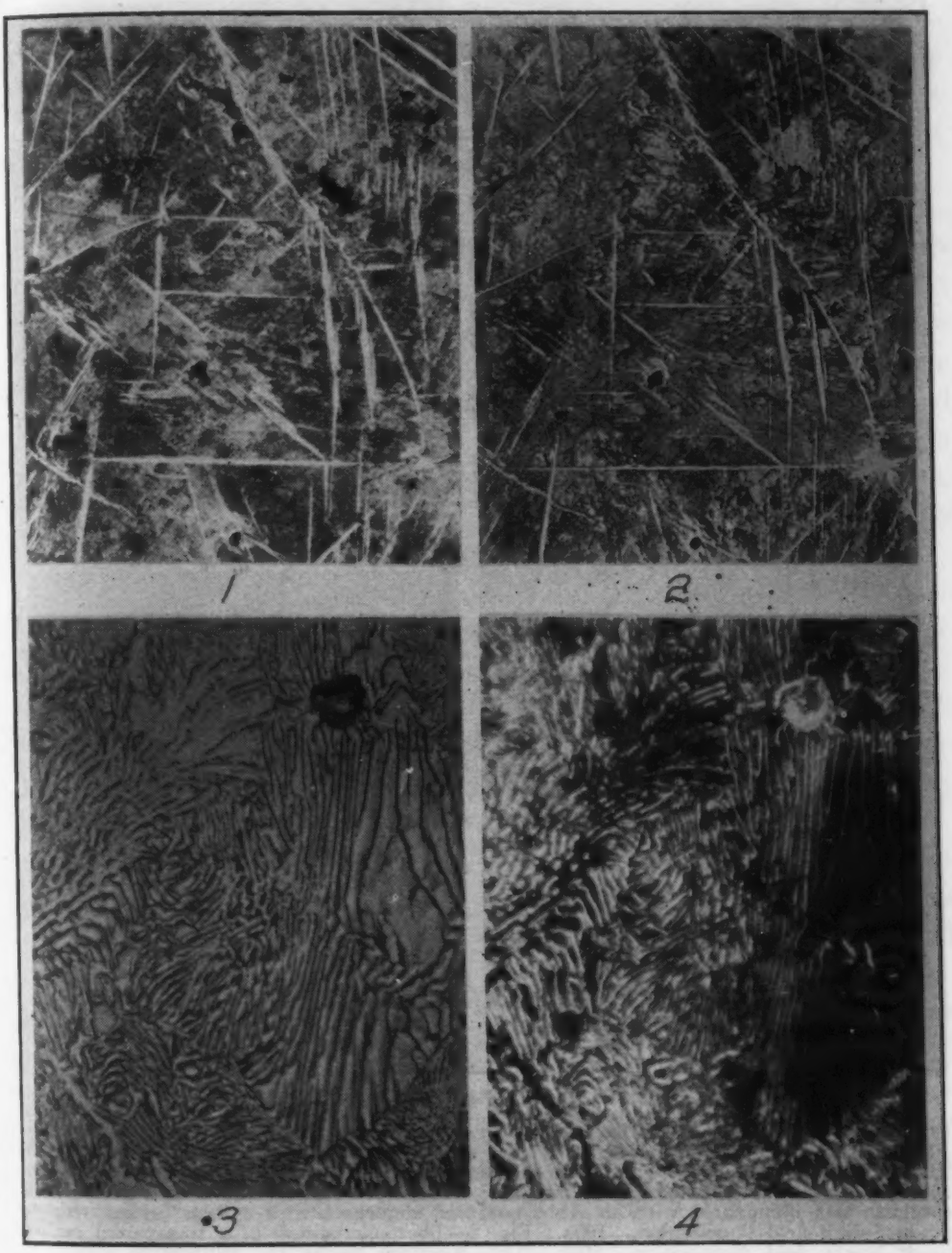

Fig. 1—Photomicrograph of a 1.5 per cent carbon steel using vertical illumination. 150x. Fig. 2—Photomicrograph of the transparent replica of Fig. 1 using bright field illumination. 150x. Fig. 3—Photomicrograph of the transparent replica of an 0.85 per cent carbon steel made with bright field illumination using an Abbe substage condenser. 500x. Fig. 4—Photomicrograph of the same replica as in Fig. 3 made with dark field illumination, the paraboloid dark ground illuminator replacing the substage condenser. This method of illumination produces a negative representation of the specimen. (In the bright field illumination, the cementite plates are white while in the dark field they are black. 500x.

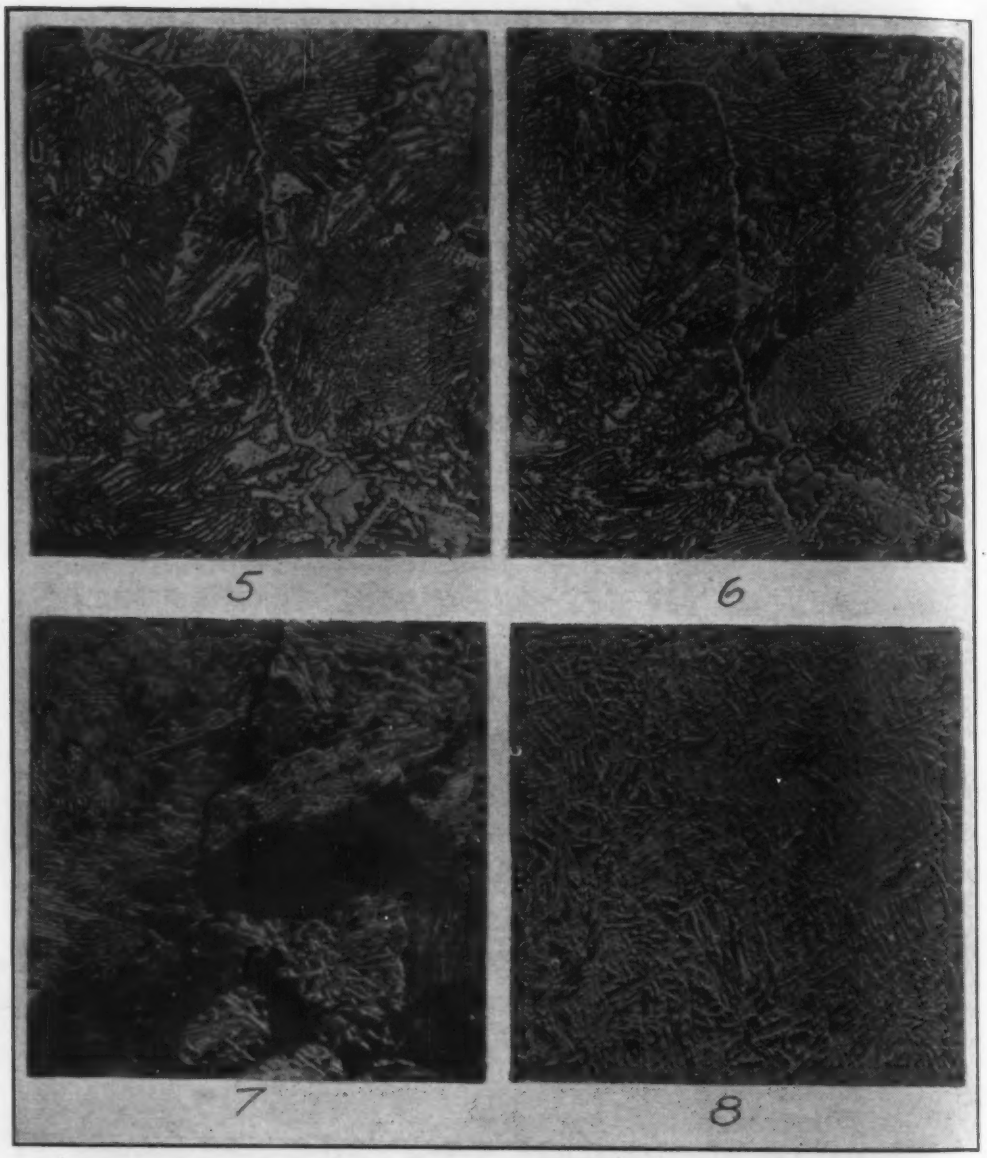

Fig. 5—Photomicrograph made of an 0.85 per cent carbon steel specimen with the use of a metallurgical microscope equipped with vertical illumination. 500x. Fig. 6—Photomicrograph of the transparent replica of the metallic specimen shown in Fig. 5. The replica was illuminated with Abbe substage condenser giving bright field illumination. 500x. Fig. 7—Photomicrograph of the same transparent replica shown in Fig. 6. This specimen was illuminated with an Abbe substage condenser with a dark ground stop to produce dark field illumination. 500x. Fig. 8—Photomicrograph of a transparent replica using bright field illumination. 500x. This specimen shows the martensitic structure. The substage iris diaphragm was reduced and decentered giving the appearance of relief to the specimen.

Results Obtained

In order that comparisons may be made between photomicrographs of the original metallographic specimen and the transparent replica of it, photomicrographs in Figs 1 to 8 inclusive, are pre-

sented. Photomicrograph in Fig. 1 was made directly from the metallic etched specimen, using vertical illumination. Photomicrograph in Fig. 2 was made from the transparent replica of the metallic specimen of Fig. 1, using bright field illumination. These photomicrographs were made at 150 diameters magnification of a 1.50 per cent carbon steel showing cementite needles.

Photomicrographs in Figs. 3 and 4 were made of a transparent replica taken from an 0.85 per cent carbon steel at a magnification of 500X. These photomicrographs show pearlite. Fig. 3 was made with bright field illumination, using the Abbe substage condenser, the aperture being somewhat reduced with the substage iris. Fig. 4 was made with dark field illumination, the paraboloid dark ground illuminator replacing the substage. This produces a negative representation of the specimen. In bright field illumination the cementite plates are white, while in dark field illumination they are black, as can be seen by comparison of the two pictures.

Photomicrograph, Fig. 5 was made of an 0.85 per cent carbon steel specimen on a metallurgical microscope using vertical illumination at a magnification of 500X.

Photomicrograph, Fig. 6 was made of a transparent replica taken from the specimen shown in Fig. 5. The specimen was illuminated with an Abbe substage condenser giving bright field illumination.

Photomicrograph, Fig. 7 was made of the same transparent replica shown in Fig. 6. The specimen was illuminated with an Abbe substage condenser and a dark ground stop, to produce dark field illumination.

Photomicrographs in Figs. 5, 6 and 7 all show the same area of the specimen.

Photomicrograph Fig. 8 was made of a transparent replica in bright field illumination at a magnification of 500X, the specimen showing martensite. The substage iris diaphragm was reduced and decentered giving the appearance of relief to the specimen.

DISCUSSION FOLLOWING J. S. VANICK AND H. K. HERSCHMAN'S PAPER ENTITLED, "PROTECTIVE COATINGS FOR SELECTIVE CARBURIZATION" PRESENTED BEFORE THE FIFTH ANNUAL CONVENTION OF THE SOCIETY, PITTSBURGH

PAPER PUBLISHED IN SEPTEMBER, 1923 TRANSACTIONS

CHAIRMAN P. D. MERICA: Gentlemen, this paper is open for discussion.

D. J. DEMOREST: I would again like to hear what the author said about the nitrogen in Armco iron. Did I understand that the nitrogen in Armco iron was higher than other materials?

J. S. VANICK: Yes. It is higher than most other material used for carburizing purposes; the carburizing steels are what I have reference to.

W. J. MERTEN: Mr. Vanick states that the copper plating as a protective coating is quite a simple application in his work. In a plating plant he will find it quite different. We have never found an ordinary cyanide bath to give us a coating that will protect over long periods. We have always had to go to an acid bath, and even then the porosity of the coating is of such a character that the copper plating does not offer the protection that is required for absolute protection against carburization. It is sometimes absolutely necessary, in commercial work, that complete protection be attained, but Mr. Vanick's statement that suitable copper plate coatings are readily obtained in commercial practice, is quite unwarranted.

J. S. VANICK: One of the drawbacks to the copper plate coatings is the variable condition of the surfaces plated, and very many other defects which arise in the deposition, must be counteracted. The reason for using cyanide plating was the result of some recent work published by the Electroplaters society, where that method had been recommended. Copper flash and sulphate following, is in general use, but it has been found that this cyanide bath, under the conditions as they are mentioned here, will give very good results. At least, it has done so in this particular experimental case.

R. W. WOODWARD: I think the point is well taken. The character of the copper coating makes a great deal of difference on the selective effect that is obtained. I have found that the ordinary plating methods of the electroplating factories, such as those used by the electrical fixture manufacturers, do not give adequate protection against carburization. In using such a copper coating under laboratory conditions, one can generally get excellent protection against carbon penetration.

Another thing which I have observed, is that a fine-grained coating is practically necessary. Such a coating can be obtained by first flashing on copper and then nickel. This leads me to suspect that an alternate built-up layer of nickel and copper, would give far greater protection, and probably in a much less thickness, than an entire coating of copper.

J. S. VANICK: Perhaps the general objection to that is that of complicating the procedure by more handling of parts which are to be plated.

CHAIRMAN P. D. MERICA: It might be interesting to mention that in some recent tests with which I happened to be familiar, nickel plating was tried instead of copper plating, and absolutely failed to protect the material from carburization. The carbon apparently went through as if the nickel were not there, testifying to the solubility of carbon in nickel and its rather rapid diffusion rate, presumably. I am not absolutely certain that some of that infiltration may not have been due to the porosity of the nickel coating.

R. W. WOODWARD: My point was that the use of the nickel would be to break up the copper deposit and keep a very fine-grained copper deposit. I think that would be the best method of protection.

J. S. VANICK: I think fine-grained deposits can likewise be obtained with high current densities.

W. J. MERTEN: In my work I have found that if you lay a sufficiently heavy copper body on a piece of steel, you do not need to take any precautions to avoid the infiltration—it effectively prevents any penetration of carbonaceous gases, and the lines of demarcation are very sharply defined. The thickness and the solidity of the copper is the only requirement and the amount of gas absorbed by the copper, is probably the only factor that is offering the protection.

DR. S. L. HOYT: Do I understand you to say that you do not get a dense enough copper coating from the cyanide bath, in order to get the protection you need? Just what is the objection to cyanide?

W. J. MERTEN: In my plating practice, the first coating is obtained by a flash cyanide deposition which is very superficial. The second heavy coating is obtained by the acid deposit on top of the cyanide flash. I have never been able to obtain a sufficiently thick coating from the cyanide bath. Time limitations in the shop are such that one cannot, unless the time is very much prolonged, obtain a sufficient thickness. One would have to resort to an acid bath in order to get the proper thickness of coating in the time period available; at least that is my experience. It may, however, be that your researches have removed some of those objections, but they are present in the shop.

DR. S. L. HOYT: There is such a thing as a rapid cyanide bath. At least, one that is better than the old style bath, and I am a little surprised to hear anybody say they do not get dense copper in a reasonable length of time from the cyanide bath. I had supposed it was quite possible commercially.

FRANK WHEELER: At the Franklin company, we do considerable copper plating with a cyanide bath. We use a very high current density, of about 50 amperes per square foot, and I believe we get entirely satisfactory results.

DISCUSSION FOLLOWING W. P. WOOD'S PAPER ENTITLED, "THE SEASONING OF STEEL," PRESENTED BEFORE THE FIFTH ANNUAL CONVENTION OF THE SOCIETY, PITTSBURGH

PAPER PUBLISHED IN OCTOBER, 1923 TRANSACTIONS

CHAIRMAN P. D. MERICA: Gentlemen, is there any discussion of Mr. Wood's paper?

D. J. GRAINGER: Mr. Chairman, I would suggest that Mr. Wood give us his opinion of what conclusion he came to.

W. P. WOOD: For consideration, the results should be divided into two parts, first the increase in ductility, secondly, the loss in tensile strength of some of the alloy steels. The increase in ductility, I believe, may be explained as representing the attempt of the steel to reach its final state of equilibrium with regard to structural constituents and physical properties. It is becoming more and more evident that this condition is not attained quickly.

Concerning the apparent decrease in tensile strength, I do not believe it would be advisable to attempt an explanation until further work had thoroughly proved the point. Once that were proved, the change would probably have to be explained along the line of a gradual internal rearrangement of constituents due to the nature of the alloy.

A. L. DAVIS: I take it the mechanical work performed in filing up the finish was very small.

W. P. WOOD: A few thousandths of an inch. The final finishing was done with the file after the normalizing.

J. M. LESSELLS: I would like to say, since we believe that the ratio of elastic limit to yield point is in certain cases for ferrous materials a measure of the internal stress in the material, I would recommend to the speaker that further tests would be very interesting if he could give us data on the elastic limit and yield point, the elastic limit being taken with a delicate extensometer.

I would also like to ask the speaker on what kind of testing machine these values were obtained.

W. P. WOOD: We used a 100,000-pound Universal.

J. M. LESSELLS: I would like to offer this, it is not a suggestion, rather a thought; if you take a piece of rolled medium carbon steel, and obtain a tensile test curve, the yield point and elastic limit have a definite ratio to each other, and the ultimate has a definite value—if you anneal it thoroughly, the elastic limit and yield point approach each other, and if it is tested in a certain class of machine, they may coincide, and the ultimate stress decrease.

I am just offering that to see if it has any bearing on the results that you obtain.

CHAIRMAN P. D. MERICA: I would like to ask if any tests were made on the heat-treated steel other than normalized?

W. P. WOOD: No.

W. J. MERTEN: Since all pronounced ageing results are on alloy steels, does not it indicate severe internal straining and ageing then becomes the relieving of these internal strains with consequent change in physical properties? The silicon steel, especially, indicates this very largely. It seems that accelerated ageing by drawing at proper heat should have been applied to these steels in order to avoid excessive ageing.

DR. G. K. BURGESS: I might state, as a matter of information, that Mr. Scott at the Bureau of Standards is working in connection with the committee on gage steel on the subject of the dimensional changes and also the distribution of strains in several types of steel which we have hoped were satisfactory for gages. The general proposition is, that it is the most difficult thing to get a piece of steel which is in a permanent condition of rest, either as to dimensions, internal strains, or as to its physical properties. I imagine that Mr. Scott's work will be available for publication within the coming year. We are getting out progress reports, and if any one is interested and will address Mr. Scott he will see that you get them.

There has been a great deal of work done on this subject that has just come to light, and I frankly think, in support of the remarks that have already been made, that in doing work of this kind, not only the tensile, elongation, and reduction should be taken, but also the proportional limit, the yield point and elastic limit in determining these properties sufficiently. I do not think that two observations on time are sufficient, but that the first observation should be taken within an hour after the last operation and then at a series of three or four corresponding stated intervals. I doubt if it is advisable to base very serious conclusions on two or three samples.

O. W. ELLIS: One point in connection with these tests, came to my mind two or three years ago when carrying out tests on rods of brass. These rods were tested, first, on receipt; second, a year after they had been received, and third, two years after they had been received. We obtained very interesting results, but on thinking over those results we began to realize that they really did not represent what was happening in the rod.

The moment that a test sample is taken, for tensile test, from any rod that is under internal strain, we change the condition of the rod and vary the intensity of internal stress the moment it is machined. Hence, in any consideration of the meaning of any such tests as have been reported here, consideration must also be taken of the fact that the internal condition of the same portion of the rod tested, is different from the condition of that portion of the rod before the test piece was taken from the material.

NOTES FROM THE U. S. BUREAU OF MINES*

EXPERIMENTAL work on a laboratory scale on the desulphurization of coke by seam, conducted by the Department of the Interior and the Carnegie Institute of Technology at the Pittsburgh experiment station of the Bureau of Mines, has demonstrated that the steaming process effects a greater sulphur removal than is possible with other processes. The economic importance of the results of these experiments is that they point the way to future utilization of enormous reserves of high-sulphur coals not now suitable for coke making. At the present time only low-sulphur coals are used for this purpose.

In a report giving the results of these experiments, made by Alfred R. Powell, associate chemist, Bureau of Mines, and John H. Thompson, research fellow, Carnegie Institute of Technology, it is pointed out that sulphur in metallurgical coke gives rise to many problems and difficulties in furnace operations. Over 1.25 per cent of sulphur is likely to produce an inferior grade of iron. Sulphur will, in addition to causing trouble in the furnace, make it difficult, if not impossible, to work the iron. Any process for removing this deleterious substance from the coke is therefore of value to both the manufacturer and consumer of coke, if the cost is not prohibitive.

The average annual coke production of the United States during the last 10 years has been 45,404,000 tons. Approximately 60 per cent of this total has been used in metallurgical industries, chiefly iron and steel, while the remainder was consumed for domestic or gas-making purposes. The coal used in producing this quantity of coke represents annually approximately 15 per cent of the total of bituminous coal mined in the United States.

Any saving in the production of coke, even though it be relatively small, or any improvement made in the finished product, will amount to large sums. The removal of part—even a small part—of the sulphur from the coke offers such an improvement. In addition to solving one of the principal problems of the steel industry, this removal would create a much greater coal supply from which the coke producer would draw his raw material. Many of the coals of Pennsylvania, West Virginia, and Kentucky are so high in sulphur that their use for the manufacture of metallurgical coke is prohibitive, without preliminary treatment by the present known means of coal cleaning, principally coal-washing, which is not always an effective remedy. Illinois has the greatest potential coal supply of any state in the Union, with the possible exception of Wyoming, which is underlain by immense fields of low-grade sub-bituminous coal. Nearly all of this Illinois coal will make good coke, if not alone, when used in proper mixtures with other coals; but in most cases the sulphur content is above the limit fixed by present standards. This can not be reduced by washing in some cases, due to the peculiar combinations of the sulphur compounds in the coal. The possibility of removing part of the sulphur should interest the coal mine

*Information Obtained from the February and March, 1924, Press Memorandum of the Department of the Interior, Bureau of Mines, Washington.

operator as well as the coke producer; and a new market would be created for the product of the former, which has heretofore only been available to those mining a low-sulphur coal.

Many processes have been tried for the removal of sulphur from coke, including steam; but most of them have not met with any degree of success. The investigators at the Bureau of Mines laboratories found that between 10 and 15 per cent of the total sulphur in the coke is removed by simple steaming at 750 degrees Cent. With alternate vacuum and pressure treatment the desulphurization is increased to 20 to 25 per cent. Furthermore it is believed that the steaming is much more beneficial than the actual sulphur reduction indicates, since the sulphur removal is almost entirely taken from the surface of the coke, and this surface sulphur may be the part that is easily absorbed by the iron in the blast furnace.

The recent rapid growth of the by-product coking industry serves to simplify the matter of a cheap steam supply. Large quantities of heat are now allowed to go to waste, but this heat could be well utilized in the generation of steam. Thus the process of steam coke could be made comparatively inexpensive.

The investigators point out that, so long as the supply of low-sulphur coals is available, the steaming of coke could not be termed an industrially feasible process. However, when it becomes necessary to resort to the use of higher sulphur coals for the manufacture of coke, the improvement of the coke through steaming may be of sufficient value to warrant the expense of the process. Of the many processes thus far tried, steaming results in the greatest removal, and offers the best possibilities for adaption to the coke industry.

The results of this investigation are embodied in Bulletin 7 of the Coal Mining Investigations Series, which may be obtained from the Carnegie Institute of Technology, Pittsburgh.

Production of Sponge Iron

A new process for the production of sponge iron has been developed by the Department of the Interior, in co-operation with the University of Washington, as the result of experimental work conducted during the past three years at the Northwest experiment station of the Bureau of Mines, Seattle. Sponge iron, because of its porous structure and consequent exposure of an extremely large surface of metallic iron, is especially adaptable to the precipitation of copper, lead and other metals from their solution. The development of a process by which sponge iron may be made cheaply from iron ore and low-grade coal and afterward converted into iron and steel products by treatment in the electric furnace would be of special economic importance to the Pacific coast region of the United States, a territory remote from the larger iron and steel producing centers, but endowed with cheap electric energy to

take the place of the expensive coke that would otherwise have to be utilized in iron and steel production.

On account of the removal of oxygen from iron oxide ore, the structure of sponge iron is very porous, an extremely large surface of metallic iron being exposed. As a result, sponge iron is an active reducing agent and precipitates metals from solution with greater speed than do the more massive forms of iron, such as steel scrap and iron turnings. The Bureau of Mines considers that sponge iron will probably be used extensively for the precipitation of copper, lead, and other metals from hydrometallurgic solutions. The many advantages afforded by the use of sponge iron for this purpose should cause an expansion of processes involving leaching and precipitation.

Its value as a reducing agent should cause sponge iron to replace other forms of metallic iron now used as a reagent in certain chemical production processes. New processes utilizing cheap sponge iron may be developed to take advantage of the great reactivity of metallic iron in this form. These processes could reconvert to sponge iron any iron oxide obtained from the reaction.

The possibility of making sponge iron and converting it to steel without passing through the stage of pig iron production has been suggested from time to time and hundreds of so-called "direct steel" processes have been proposed or tried during the past century. Unquestionably, the production of steel from sponge iron has theoretical advantages over present standard methods. Moreover, the production of both steel and pig iron from sponge iron has economic advantages in certain localities. In regions remote from iron and steel producing centers where coke is expensive and electric energy cheap, sponge iron made cheaply from iron ore and low-grade coal can probably be converted into iron and steel products by treatment in the electric furnace in competition with the imported goods. The fact that both the electric melting and sponge iron production processes can be conducted economically on a small scale makes such a proposed process particularly advantageous in communities that do not consume much iron or steel. Electric furnace processes, being inherently expensive, are advocated for the production of iron and steel only where unusual conditions prevail.

There is some hope that sponge iron can be briquetted and melted in the open-hearth steel furnace without too much oxidation. If this could be accomplished a much larger field of usefulness would be opened up for cheap sponge iron.

In the process developed by the Bureau of Mines and University of Washington investigators, almost any type of iron ore is satisfactory for the production of sponge iron. Experiments conducted at the Seattle station showed that similar results are obtained with magnetite, hard and soft hematite, limonite and sintered hematite. It is probable that sponge iron will be made from such by-product materials as flue dust, pyrite cinder, various slags of high iron content, and iron oxide sludge.

The Bureau of Mines process consists in passing a mixture of iron ore and coal through a rotating kiln heated at one end to a temperature sufficient to convert iron oxide to metallic iron, discharging, cooling, and separating the sponge iron from the residual coke and siliceous material on a magnetic separator.

Details of these experiments are given in Serial 2578, by Clyde E. Williams, Edward P. Barrett, and Bernard M. Larsen, which may be obtained from the Department of the Interior, Bureau of Mines, Washington.

NOTES FORM THE U. S. BUREAU OF STANDARDS*

The Effect of Molten Copper on Wrought Iron

DURING the past month the Bureau of Standards carried out an unusually interesting test on wrought iron rods employed for stirring copper. The manufacturers of these rods reported that although they had been tested as to mechanical properties and found to be satisfactory they proved very unsatisfactory in service. A metallographic examination of the iron after deterioration showed an embrittlement of the material ,either caused or accompanied by the intercrystalline penetration of the copper into the iron. An attempt was made to reproduce experimentally the same condition in wrought iron bars of known mechanical properties by heating them in molten copper. Specimens simply immersed in a copper bath showed no structural evidence of embrittlement of the iron by intercrystalline penetration of the copper. However, repeatedly bending the hot iron rod while immersed in the copper some intercrystalline penetration was obtained which indicates that this mechanical condition is probably one of the contributing causes of this unusual type of deterioration of the wrought iron.

The Effect of Annealing on Galvanized (zinc) Coatings

In compliance with a request received a short time ago the Bureau has been investigating the relative merits of galvanized materials which have undergone a special annealing treatment as compared with those which have passed through the ordinary galvanizing process. This is of interest because galvanized materials which have been subjected to such annealing treatments are now being marketed under special trade names and some rather unusual claims are being made for them. The investigation will be concerned mainly with the effect of low temperature annealing upon the ductility of the zinc coatings of wire (as shown by the bend test) and the resistance of such annealed coatings to chemical reagents such as copper sulphate which is a much used commercial test for galvanized wire. A study will also be made of the structural changes in the coating resulting from the annealing.

*Information Obtained from Technical News Bulletin No. 83. Published by the Department of Commerce, Bureau of Standards, Washington.

Dictionary of Specifications

On Feb. 18 the chairman of the three committees of the representative board organized to act in an advisory capacity to the Department of Commerce in publishing the dictionary or handbook of specifications, met at the Bureau of Standards to discuss interrelated problems and to formulate plans for their solution with full knowledge of the nature and progress of the work which the Bureau has been carrying on.

Committee No. 1 on classification is now giving consideration to the proposal of its chairman that the decimal system of classification be recommended for use.

Committee No. 2 on form and size has under consideration the proposal of its chairman that the loose-leaf form in standard catalog size be recommended.

The chairman of committee No. 3 on scope has proposed for consideration the recommendation that a system having great flexibility be adopted as a means of selecting material for the handbook. This would admit the publication of annotations relating to certain existing specifications that are readily available as well as the direct publication of certain other specifications, the supply of which is very limited. The matters which are now being discussed by the three committees will be presented for the consideration of the advisory board at its next meeting to be held about two weeks hence.

Refractories for the Melting of Platinum

Last month a sample of fused zirconium oxide was obtained from a company which is developing the production of fused zirconia on a commercial scale. Small crucibles of fused zirconia have been made in the laboratory without an added oxide bonding material and with additions of 20 per cent thoria or 15 per cent aluminum. Very promising results have been obtained since several of the crucibles have satisfactorily withstood very sudden and uneven heating in the oxyacetylene flame and even quenching in water from temperatures as high as 1700 or 1800 degrees Cent. Actual melting tests with platinum will be carried out in the induction furnace as soon as possible.

Meeting of the Committee on Gage Steels

A meeting of the gage steel committee was held at the Bureau of Standards, Feb. 16, sixteen members representing gage manufacturers, steel makers, army and navy ordnance departments, technical societies and the Bureau being present. The completed work of the committee was discussed and further work planned. It was agreed that the work had progressed sufficiently far to warrant practical service tests and with this object in view the secretary was directed to present the work of the committee before the automotive industries in order to secure their co-operation. If the co-operation of these industries is secured, it will make possible the carrying out of service tests rapidly because of the extensive and heavy use of gages in automobile

manufacture. Plans were made for the immediate determination of the effect of the more important variables involved on the wear of gages.

Accidents At Metallurgical Plants

Statistical data compiled by the Department of the Interior, through the Bureau of Mines, indicate that the larger metallurgical works in the United States enjoy an advantage over the smaller plants in overcoming the accident hazards to which workers in metallurgical industries are exposed. The resources back of an industrial enterprise necessarily determine the expenditures that may be made for accident prevention work and for other purposes, the Bureau of Mines points out. To the extent that the number of men employed indicates a plant's resources and equipment for safety work, figures based on the operators' reports for 1922 show that mills and smelters employing 200 or more men each suffered fewer accidents for any given number of employes than did smaller plants, those employing less than 200 men each. Accidents were most frequent where only 1 to 25 men were employed. Mills employing 300 or more men each had an accident rate lower than that for any other group; next in order were mills employing 50 to 99 men; the third lowest rate was for mills employing 200 to 299 men each. For smelters the lowest accident-frequency rate was at plants employing 200 to 299 men, and the second lowest rate at plants employing 300 or more men.

Detailed statistics regarding accidents at metallurgical works in the United States are given in Technical Paper 350, which may be obtained from the Department of the Interior, Bureau of Mines, Washington.

New Radium Research Laboratory

A laboratory for radium research, with special reference to the study of the chemical effects of radium radiations, has been established in Washington by the Department of the Interior under the direction of the chief of the Division of Mineral Technology, of the Bureau of Mines. This work has hitherto been conducted at the rare and precious metals station of the Bureau of Mines at Reno, Nevada. Prior to transfer of the radium equipment to Washington, the following reactions produced by alpha radiation were studied: decomposition of carbon monoxide; the reaction between carbon monoxide and oxygen; reduction of carbon monoxide by hydrogen; reduction of carbon dioxide by hydrogen; reaction between methane and oxygen; and decomposition of methane. The final gaseous mixtures resulting from several of these reactions await analysis, which will comprise the first stage of the experimentation to be done at Washington.

The main program includes the study of gaseous reactions produced by alpha radiation from radon (radium emanation). Among the first reactions to be studied will be the radiation, respectively, of ammonia and of a mixture of carbon-monoxide and hydrogen.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 120. *How does the carbon content affect the secondary hardness of high speed steels?*

QUESTION NO. 121. *What are thumb nail cracks?*

QUESTION NO. 122. *What are the mechanical properties of stainless steel and stainless iron?*

QUESTION NO. 123. *What are the advantages of using a hot soapy-water quenching medium?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 93. *What are the more common methods of quenching ordinary taps? Are they quenched all over and the shanks drawn, or are they quenched only on the threaded portions; or are both the threaded portions and the tangs quenched, leaving the center portion of the shanks soft?*

QUESTION NO. 96. *Can the structure of a piece of steel be determined by the microscope applied to the fracture of a cross section, without polishing and etching the fracture, say of a stamping die 6 x 2 x 3½ inches, that has been hardened and broken in half, that is, are the different structural phenomena known as austenite, martensite, sorbite, ferrite, etc., so determinable?*

QUESTION NO. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel* 6 *x* 2 *x* 3½ *inches?*

QUESTION NO. 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc?*

QUESTION NO. 110. *Do notched bar impact specimens give more uniformly constant results than an un-notched bar?*

QUESTION NO. 111. *How is the reduction of area a flat tensile test specimen usually obtained?*

ANSWER. The reduction of area of a flat tensile test specimen is the product of the width by the thickness, measured at the point of rupture of the specimen. The per cent reduction is this area divided by the original area of the specimen. The determination of the exact cross section area of a flat tensile test specimen is a difficult procedure, due to the fact that it is difficult to obtain the exact cross sectional dimensions by the means of calipers when angular fractures occur. The cross section at the point of rupture is seldom rectangular, the lateral faces and edges of the bar are generally concave.

A planimeter is frequently used in determining the reduced section.

QUESTION NO. 114. *Is it possible to obtain an accurate conversion table for obtaining Brinell hardness number from the Rockwell or scleroscope values?*

ANSWER. In answer to this question, Dr. G. K. Burgess, director of the United States Bureau of Standards, comments as

follows: "In our opinion, conversion tables for obtaining the Brinell hardness from the Rockwell hardness value or from the scleroscope value, should not be used. We have never attempted to make conversion tables of the kind, so we have no proof that it cannot be done, but we believe that the value should be reported as the hardness by the method which was used in determining it.

"It can be readily seen, that if for a given material there is a different relation between the Brinell hardness and the tensile strength and that later it has been found more convenient to use the Rockwell hardness tester and the conversion table to obtain the Brinell hardness from the Rockwell value, that serious errors may result. In our opinion, manufacturers can find the relation which exists between two hardness values for the particular material which they are using. This conversion factor should, however, not be used for other materials nor for materials of the same kind but of different chemical composition."

ANSWER. By Stanley P. Rockwell, metallurgical engineer, Hartford, Conn.

One of the difficulties in securing conversion lies in the fact that very few materials are homogeneous. The annealed products, especially steel and non-ferrous metals, are more apt to be homogeneous than those heat-treated, cooled, worked, decarburized, cyanided, or case hardened. It must be remembered that the Brinell is testing the metal at a greater depth from the surface than that metal tested by the Rockwell, likewise the scleroscope is testing even closer to the surface. The theory of conversion is fully discussed in the writer's paper, entitled "The Testing of Metals for Hardness" given before the annual convention of the American Society for Steel Treating at Indianapolis and published in TRANSACTIONS, August, 1922.

One of our middle west universities is now working out on all the standard S. A. E. steels, accurate conversion data which, when finished, will be available to all.

QUESTION NO. 115. *How is the fiber stress of a shaft calculated? Is there a relation between fiber stress and tensile*

strength and if so, can the fiber stress be estimated if the tensile strength is known?

ANSWER. By Prof. George C. Priester, department of mathematics and mechanics, University of Minnesota.

The greatest unit shearing stress, developed in the outer fibers of a round shaft, is calculated by the following formula:

$$S = \frac{16\ T}{\pi\ d^3}$$

where S = the unit shearing stress in pounds per square inch
T = the twisting moment in inch-pounds
d = the diameter of the shaft in inches
and $\pi = 3.1416$

The stress developed in a shaft, subjected to a twisting moment only, is a shearing stress. There is no definite relation between the maximum shearing stress and the maximum tensile stress of a piece of metal or wood. For example, the maximum unit shearing stress is less than the maximum unit tensile stress in the case of ordinary steel and greater in the case of cast iron.

QUESTION NO. 116. *Can a zinc bath be used as a heating medium in substitution for a lead bath? If not, what are the objections to its use?*

ANSWER. By A. N. Armitage, metallurgist, Columbia Steel Corp., Pittsburg, Cal.

A zinc bath would be a very unsatisfactory heating medium for a number of reasons. The range is short and zinc melts at 787 degrees Fahr. If heated over 900 degrees Fahr. there will be a considerable zinc loss through drossing. Furthermore, the zinc will coat the steel quite considerably. The hot dip process of galvanizing consists of dipping the articles in hydrochloric acid and then immersing them in the molten zinc bath. The zinc will adhere to the steel parts even without the preliminary acid dip.

ANSWER. By R. B. Schenck, metallurgical engineer, Buick Motor Co., Flint, Mich.

The main objection to the use of zinc as a heating medium for the heat treatment of steel parts is that it has a tendency to adhere to the steel being treated. This property of adherence in addition to the low-boiling point of the metal and its tendency to fume, makes zinc entirely out of the question as a substitute for lead.

QUESTION NO. 117. *Does cooling molten metal rapidly eliminate segregation?*

QUESTION NO. 118. *Is a small percentage of chromium desirous in carbon tool steel? What is its advantage or disadvantage?*

QUESTION NO. 119. *What is the advantage of sulphuric acid as a quenching medium?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

BURNING OIL IN THE AIR FURNACE. By A. V. Landschoot, in *Foundry*, No. 51, page 862, 1923.

This article gives a discussion of the merits of fuel oil burning in connection with the melting of malleable iron.

ROLE OF COPPER IN CASE CARBURIZING. By O. A. Knight and E. A. Thomas, associate professor of metallurgy and graduate student, respectively, Pennsylvania State College, State College, Pa., in *Forging, Stamping and Heat Treating*, January, 1924.

This paper reports the experimental investigation that the authors have made and indicates that the action of copper in preventing carburizing at operating temperatures, is physical rather than catalytic. Considerable data is included in this article.

QUALITY OF ELECTRIC AND OPEN-HEARTH STEELS. By B. E. L. De Mare, in *Iron Age*, Vol. 113, No. 5 Jan. 31, 1924.

This paper discusses the three steel making processes which are compared with each other. The object of the comparison is to explain the metallurgical conditions during the final or settling-up period of each process, which determines the quality of the steel produced and thus shows the possibilities of modifying these conditions in order to improve the quality.

REMOVING DUST FROM BLAST FURNACE GASES. By N. H. Gellert, president, Gellert Engineering Co., Philadelphia, in *Iron Age*, Vol. 113, No. 6, February 7, 1924.

The above is an abstract of a paper read before the Pueblo Society of Engineers, Pueblo, Colo., Dec. 17, 1923, and discusses the electrolytic process of removing dust from blast furnace gases. Also it contains a description of the electrolytic process installed by a western corporation. It also gives the action of corona discharge.

MACHINING SHELDON BRAKES, DRUMS AND SPIDERS. By Fred H. Colvin, in *American Machinist*, Vol. 60, No. 11, March 13, 1924, page 387.

This article states that special fixtures and tools are being devised for

machining work of odd shape. Detail photographs of fixtures are shown so that their construction can be more readily understood.

WHAT IS STEEL? ANOTHER ANSWER. By Dr. Albert Sauveur, in *Iron Age,* Vol. 113, No. 8, Feb. 21, 1924.

This paper was presented by Dr. Sauveur as the first Dr. Henry Marion Howe Memorial lecture, inaugurated by the Mining and Metallurgical Engineers, and was delivered on Feb. 19, before the annual meeting of the institute. A brief of the work of Dr. Howe introduces this paper. The author reiterates Dr. Howe's teaching that new theories and hasty conclusions should be carefully weighed.

An explanation of the red-shortness of metals when rolled at certain temperatures, is a feature, as well as some of the results revealed by tensile tests.

THE GRAPHICAL SOLUTION OF HELICAL GEAR PROBLEMS. By Franz Szabo, in *American Machinist,* Vol. 60, No. 11, March 13, 1924, page 391.

While valuable data for making helical gear calculations has been published from time to time, giving considerable though necessary mathematics, not much has been written regarding the graphical solution of these problems. The above article states that an approximate solution to the problem is easily obtained, and gives a method for investigating the characteristics of helical gears, eliminating trial calculations. The author states that the method discussed may be adapted to all conditions.

NEW USE FOR REFUSE REFRACTORY MATERIAL. By S. F. Walton, ceramic engineer, Northern Refractories Co., Ridgway, Pa., in *Iron Age,* March 13, 1924, page 786.

This article states that old fire clay brick-bats when ground up with a bond will form a highly refractory mortar at a very moderate cost. Several photographs are given of walls which have been repaired by applying a coating of cement made of ground firebrick and bond.

COTTRELL ELECTRICAL PRECIPITATION PROCESS. By Dr. Alfred Stansfield, professor of metallurgy, McGill university, Montreal, Canada, in *Fuels and Furnaces,* March 1924, page 269.

This paper gives a brief review of the various methods of cleaning gases, and a detailed account of the application of the Cottrell precipitator to blast-furnace gases.

TREND IN THE SCIENCE OF METALS, By Dr. Zay Jeffries, in *Iron Age,* Vol. 113, No. 8, February 21, 1924.

This article is a portion of a paper which Dr. Jeffries presented before the American Institute of Mining and Metallurgical Engineers in New York, Feb. 18, and discusses the relative growth of the steel and nonferrous industries, and the relative importance of the various metals in use.

MICROGRAPHIC STUDY OF PLAIN CARBON STEEL. By Richard Rimbach, metallurgist, Pittsburgh, in *Forging, Stamping and Heat Treating,* January, 1924.

The author has studied the structure of plain carbon steels resulting from various treatments and has incorporated a very complete set of photomicrographs showing the effect of the various heat treatments on a 1.12 per cent carbon steel.

STEEL AND THE PETROLEUM INDUSTRY. By Francis B. Foley, in *Iron Age,* Vol. 113, No. 7, Feb. 14, 1924.

This is an abstract of the author's paper which was presented before the fourth annual meeting of the American Petroleum Institute in St. Louis, and discusses the handling of tool steel in the oil drilling field and the desirability of closer control over the quality of the steel being used.

PRESENT STATUS OF THE CONTACT SULPHURIC ACID INDUSTRY IN RUSSIA. By J. R. Minevitch and W. M. Malisoff, consulting chemical engineers, New York City, in *Chemical and Metallurgical Engineering,* Vol. 30, No. 10, March 10, 1924, page 384.

The information contained in the above article was taken largely from a paper by P. M. Lookyanov entitled, "Production of Contact Sulphuric Acid," and which was published at Moscow in 1922. It gives a historical account of a technical development which reveals an interesting application of modern processes and equipment in the sulphuric acid industry.

THE DEVELOPMENT OF FERRO-ALLOYS OF TUNGSTEN AND VANADIUM. By Frederick M. Becket, metallurgist, Union Carbide and Carbon Research Laboratories, Long Island City, in *Chemical and Metallurgical Engineering,* Vol. 30, No. 10, March 10, 1924, page 391.

In this paper is given a historical narrative of the production of materials commonly used in making shock and heat-resisting steels.

REFRACTORIES FOR STEEL AND BRASS FURNACES. In *Iron Age,* Vol. 113, No. 8, Feb. 21, 1924.

The above is a special report of the twenty-sixth annual convention of the American Ceramic Society held at the Hotel Traymore, Atlantic City, N. J., Feb. 4 to 9, 1924. This report incorporates the salient features of paper presented at this meeting dealing with refractories for steel and brass furnaces.

CAUSE OF RED STAINS ON SHEET BRASS. By E. A. Bolton, in *Iron Age,* Vol. 113, No. 6, February 7, 1924.

Sheet brass manufacturers have been perplexed for a long time by the occurrence of red stains on sheet brass, and the author has discussed the many theories which have been advanced as the cause of red staining. A discussion of the various supposed causes is incorporated in this paper.

Reviews of Recent Patents

By
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110 E. 42nd St., New York City
Member of A. S. S. T.

1,471,655. Steel Manufacture. Frederick J. Griffiths and Duke N. A. Blacet of Massillon, Ohio.

This patent sets forth that the fibrous structure which is imparted to steel by certain foreign substances which are normally considered injurious thereto, may be of considerable value, when the steel is used in places where it is subjected to fatigue and vibratory stresses, and describes a method whereby the fibrous structures may be obtained. The method consists in introducing into the steel when cast into the ingot, a relatively small amount of fibrous structure producing ingredient, such as ground furnace slag, brick, dust, clay, or the like.

1,472,367. Method and Apparatus for Case Hardening. William Wallace Kemp of Baltimore, Md., assignor of one-half to William H. Van Horn of Baltimore, Md.

This patent proposes a new method of case hardening in which the articles to be case hardened are heated by means of a jet or flame, in a closed retort under such conditions that the carburizing agent may be present during the heating without igniting. In substance, the inventor proposes to introduce the heating medium, preferably gaseous, into a closed retort, in which the articles to be treated are placed, together with only sufficient air to support combustion of the heating medium. The carburizing material in the retort is thereby prevented from burning by the lack of sufficient air in the retort to sustain combustion thereof, and the advantages of direct heat for the articles in the presence of the carburizing compound is realized. To produce uniform heating of the articles being carburized the retort is provided with a rotating cage of foranimous metal or the like, in which all portions of the articles may be uniformly exposed to the heating plane.

1,472,850 and 1,472,851. Method of Cementation of Boron into the Surface of Iron or Steel. Takeo Miyaguchi of Sengagayamachi—Tokyofu, Japan.

These two patents state that it has only recently been discovered that iron or steel when combined with boron becomes tough and hard, and describes two ways to bring about the combination by cementation.

In the second patent, the piece of iron or steel is cleansed and

packed in finely powdered ferroboron in a closed furnace, and furnace is then heated to 800 or 900 degrees Cent. and chlorine gas fed into the furnace under a pressure of about two atmospheres, after one and one-half hours in the furnace the boron penetrates to about one millimeter into the metal. The first patent states that the boron cementation may be effected sufficiently by packing the iron or steel in a mixture of carbon powder and boron oxide or carbon powder and borax and then heating the same in a furnace to about 900 degrees Cent. in a reducing atmosphere. An iron plate, clay or other materials may be used to shield the portions which are not to be cemented.

1,472,860. Process for the Manufacture of Iron from Iron Ores. S. J. Vermaes of Delft, Netherlands.

This patent describes the manufacture of iron from iron ore without the usual blast furnace reactions, which comprises preheating the finely divided iron ore, mixing the heated ore in a reducing furnace with finely divided solid fuel without access of air or gases, heating the furnace externally to the temperature at which the fuel reacts with the oxygen of the ore to reduce the ore, drawing off the solid metallic ore thus formed without access of air, and melting the iron to separate it from the slag. The reduction takes place without combustion so that it is not necessary to preheat and use air (containing about 80 per cent nitrogen) as in the usual blast furnace practice, and the gas produced in the reducing furnace (CO) may be used to help heat the furnace, to preheat the iron ore, and to melt the metallic iron.

1,477,821. Electric Melting Furnace. Alfred W. Gregg of Chicago, assignor to the Whiting Corporation of Harvey, Ill.

This patent describes an electric melting furnace in which the charge is heated by radiant heat and conduction. The furnace is built with an island which is surrounded by the charge when operating. Above the island, three electrodes connected to a three-phase current supply mechanism depend through the roof of the furnace and are spaced a short distance from the bed of carbon supported by the island, through which the circuit is completed to cause the arcs. The heat from the arcs is radiated to the charge and to the walls of the furnace which conduct it to the charge. The metal trough surrounding the island is shaped as to cause a continuous circulation of the metal, and convenient means are provided for inserting the charge at one end of the furnace and withdrawing the molten metal at the other end.

1,478,062. Degasifying Agent. William A. Schench, East Orange, N. J. Assignor to the Western Electric Co., Inc., New York.

This patent deals with the problem of reducing the violence of the reaction when degasifying agents such as barium, strontium, calcium

or magnesium are added to molten metal and of securing a more even distribution of the degasifying agent through the metal and more complete removal of the occluded gases therefrom. The solution offered, is to combine a small amount of the metal to be degasified with the one or more of the degasifying metals to form a mixture or alloy. When this mixture is added to the molten metal the change in the point of volatilization of the mixture will cause a slower reaction and complete degasification of the molten metal.

1,478,366. Apparatus for Treating Iron and Iron Alloys. William H. Fisher of Los Angeles and Peter Chambers of Redondo Beach, Cal.

This patent discloses a carbonizing furnace consisting of an inner carbonizing chamber for containing the articles to be carburized and a concentric heating chamber. The carbonizing material consists of a liquid hydrocarbon which will not oxidize the steel used in the furnace and which is fed into the carbonizing chamber by a regulated feed and gasified therein by the heat from the outer chamber, the residue gas after the metal is carburized (consisting principally of hydrogen) escapes through the top of the retort where it burns with a pale flame. The color of the flame is used as an indication of the progress of the carburizing of the steel in the retort.

1,479,327. Method of Treating Steel. Hugh C. Sicard of Niagara Falls, N. Y. Assignor to United States Ferro Alloys Corporation of New York.

The inventor in this patent states that when aluminum is used as a deoxidizer for steel it combines with the oxygen of the steel to form alumina, which on account of its relatively high melting point solidifies in the steel in minute globules which upon subsequent rolling produce defects in the steel. The object of the invention is to add to the steel a metallic oxide which will lower the melting point of the alumina so as to prevent its solidification in the molten steel, and for this purpose titanic oxide is suitable. A mixture of 30 per cent titanic oxide added to the alumina will lower its melting point from about 2100 to 1300 degrees Cent.

In the practice of the invention the aluminum is added in the ladle as in the usual practice and the titanic oxide is thrown into the spout of the furnace as the metal flows out so as to be thoroughly incorporated with the metal. When the mixture of aluminum and titanic oxide is used with steels to which ferrosilicon has been added as a scavenger, the alumina and titanic oxide combined with the silica remaining in the steel to form a much more fusible combination than silica alone, which will readily escape with the slag. The titanic oxide used is preferably equal to the amount of aluminum used.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Boston—Third Thursday.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

Chicago—Second Thursday.

Hartford—Tuesday nearest 10th of month.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth building.

Philadelphia—Last Friday, Engineers' club.

Tri City—Third Thursday.

BOSTON CHAPTER

THE Boston chapter of the American Society for Steel Treating held their March meeting on the twenty-first of the month at the Trimont Mfg. Co. The meeting began with a plant visitation at 3:30 p.m. and dinner was served at 6:00 p.m. R. J. Allen, metallurgist, Rolls-Royce Company of America, Springfield, Mass., was the speaker of the evening choosing for his subject, "The Inspection of Steels Used in Automotive Construction." Mr. Allen gave a very capable presentation and much valuable discussion was brought forth.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held a meeting on Thursday, March 13 at 8:00 p.m. in the Ohio Mechanics institute. "Factors Governing the Machinability of Steels" was the subject chosen by the speaker of the evening, W. J. Harris, metallurgist, Studebaker Corp., South Bend, Ind. Inasmuch as Mr. Harris has had a number of years of experience and training along these lines his paper was very well given and much valuable and interesting discussion followed its presentation.

CLEVELAND CHAPTER

On Friday, March 28, the Cleveland chapter of the American Society for Steel Treating held their regular monthly meeting at the Hotel Winton, Cleveland Engineering Society rooms. "Drop Forgings" was the title of a paper presented by Dr. John H. Nelson, chief metallurgist,

Wyman-Gordon Co., Worcester, Mass. This company beside being one of the largest forging concerns in the country, has made a wide reputation for the high quality of their product. Dr. Nelson has been connected with the Wyman-Gordon Co. for many years, and is in a large measure responsible for establishing and maintaining their enviable reputation for high class forgings. Dinner was served at 6:45 p.m. preceding the meeting.

DETROIT CHAPTER

The Detroit chapter of the American Society for Steel Treating held a meeting on Monday, March 17 in the General Motors building, at which time, Walter A. Hildorf, metallurgist, Reo Motor Car Co., Lansing, Mich., presented a very interesting paper entitled, "Abnormal Carbon and Alloy Steels and Fracture Testing of Steel." This meeting was very well attended. Dinner was served at 6:30 p.m. in the club rooms in the same building.

HARTFORD CHAPTER

On Tuesday, March 11, the Hartford chapter of the American Society for Steel Treating held a meeting in the Hartford Engineers club rooms, at which time the chapter was addressed by Malcolm Farmer, vice president of the Stanley Works, New Britain, Conn., who chose for his subject, "Cold Rolled Steel." Mr. Farmer told of the manufacture, use and treatment of this material and how some of the difficulties encountered may be avoided. Interesting discussion followed his presentation. Dinner was served at 6:30 p.m. at the University club.

LOS ANGELES CHAPTER

The Los Angeles chapter of the American Society for Steel Treating held a dinner meeting at the City club on Feb. 28 at which time W. H. Laury, research engineer, Axelson Machine Co. presided. The speaker of the evening, C. E. Carpenter, president, E. F. Houghton & Co., Philadelphia, gave a very interesting talk on "The Trend of Modern Business." He very forcibly pictured a gradual, steady and sound business growth. He felt assured that the Pacific coast and particularly southern California were just awakening to their golden opportunities. He said that the days of antagonism in business were over and from now on competitive concerns would conduct business on sounder methods and by agreements among themselves. Through his discourse he frequently referred to humorous incidents in his life and business career. Concluding his talk, Mr. Carpenter answered a number of questions pertaining to present day topics. The chapter is indebted to William Farrar, sales agent, for the Houghton company in procuring Mr. Carpenter for this meeting.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held a meeting on Monday, March 17 at Hotel Blatz. D. M. Strickland, manager development department, American Rolling Mill Co. gave a very interesting paper on "Corrosion and Protective Coatings." Mr. Strickland gave a scientific explanation of corrosion in a very simple and clear manner. His presentation aroused much instructive discussion. Dinner was served at 6:30 p.m. preceding the meeting.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held a meeting on Friday evening, March 21 at 7:15 p. m. at the Geometric Tool Co., Westville, Conn. The heat treating department of the Bellis Heat Treating Co., at the Geometric Tool Co. was in full operation and a practical demonstration was given. One of the speakers of the evening was James W. Hook, president, Geometric Tool Co., who presented an interesting talk entitled, "Hog Island Project." W. H. Eisenman, national secretary and W. S. Bidle, first vice president, were also present at this meeting, each giving an interesting presentation. This meeting was well attended.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held their regular March meeting on the nineteenth of the month in the assembly room of the Merchants association, Woolworth building, at which time Dr. Ansel St. John, Union Carbide & Carbon Research Laboratories, Long Island City, N. Y., spoke to the members choosing for his subject, "X-Rays in the Steel Industry." This presentation was very well received by the large number in attendance. Dinner was served at Post Keller restaurant at 6:30 p.m.

NORTH WEST CHAPTER

On Thursday, March 6 at 6:00 p.m. the North West chapter of the American Society for Steel Treating attended an inspection trip to the Minneapolis Steel & Machinery Co. giving the members an opportunity to observe the equipment, methods and practices used by this company in the heat treatment of steel. Dinner was served and a very enjoyable evening was spent by those in attendance.

The chapter held its regular monthly meeting on Tuesday evening, March 18 at 8:00 p.m. at the Manufacturers' club. D. M. Strickland, manager development department, American Rolling Mill Co., Middletown, O., spoke on "Rust Prevention." He not only covered the subject of corrosion generally, but also explained the uses of the American ingot iron which has been found useful in many branches of service.

Although the subject is not directly connected with heat treating, it was very interesting and instructive to all users of iron and steel. His presentation was illustrated by a number of charts.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a meeting on Friday evening, March 28, at 8:00 p. m. at the Engineers' club. C. C. Waite, manager, electric heat treating department, Snead and Co., Jersey City, N. J., gave a very interesting paper entitled, "Electric Resistance Method of Heat Treatment," which was illustrated with lantern slides. This method is a novel process of exceptional interest metallurgically, electrically and mechanically and is especially adapted to the heat treatment or annealing of seamless tubes or rolled forms of steel, brass, duralumin and other metals. By this method, steel parts are permitted to automatically quench themselves after passing through the critical range. An educational motion picture entitled, "The Story of Steel" in six reels, was shown by the courtesy of the United States Bureau of Mines, Department of the Interior, which picture was made in co-operation with the United States Steel corporation.

RHODE ISLAND CHAPTER

The Rhode Island chapter of the American Society for Steel Treating held a joint meeting with the American Chemical society on Wednesday evening, March 26 at 7:45 at the Providence Engineering society rooms. The speaker for this evening was General T. C. Dickson, commanding officer, Watertown arsenal, who chose for his subject, "Examining Steel by Use of X-Ray Spectroscope." General Dickson spoke about the use of the X-ray in discovering flaws in steel before it has been put into use. This paper was very well received and brought forth much valuable discussion.

ROCKFORD CHAPTER

On Friday, Feb. 15, the Rockford chapter of the American Society for Steel Treating held a meeting at the Nelson hotel. J. V. Emmons, metallurgist, Cleveland Twist Drill Co., Cleveland, gave a very interesting paper entitled, "The Annealing of Tool Steels," which was illustrated by lantern slides. This presentation was followed by much instructive discussion. W. H. Eisenman, national secretary was also present at this meeting and spoke of plans and the future welfare of the society.

The chapter held its March meeting on the fourteenth of the month at the Nelson hotel, at which time G. M. Goddard, president, Goddard and Goddard, Detroit, spoke on "Some Factors in Production not Frequently Considered." This was presented in a very capable manner and proved

to be one of the most interesting papers that has been delivered before the chapter. Mr. Goddard also showed some very interesting exhibits of tools, manufactured by his company.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held a meeting on Wednesday, Feb. 27 at 7:45 p.m. at the Studebaker cafeteria. Henry Brewer, Chicago district manager, Leeds & Northrup Co., and C. L. Ritchie, Studebaker Corp., were the speakers for this meeting, Mr. Brewer choosing for his subject, "Pyrometry," while Mr. Ritchie spoke on "Selection and Testing of Sheet Steel." A very interesting and instructive discussion ensued during, as well as following the presentations.

The chapter held a meeting on Wednesday, March 26 in the Community room of the South Bend Y. M. C. A. T. H. Wickenden, International Nickel Corp., New York, formerly in charge of the M and S department of the South Bend plants of the Studebaker corporation, presented a very interesting paper entitled, "The Role that Nickel Plays in Steel." His paper was very capably presented and was followed by an interesting discussion. Dinner was served previous to the meeting at 6:45 p.m.

SPRINGFIELD CHAPTER

On Tuesday evening, March 25 at 8:00 p. m. the Springfield chapter of the American Society for Steel Treating held a meeting in the Chamber of Commerce rooms. "Carburizing and Case Hardening," was the title of an illustrated paper presented by S. P. Rockwell, consulting metallurgist, Hartford, Conn. This paper was very well received and brought forth much interesting discussion. A get-together dinner meeting was held at 6:30 p. m. at the Highland hotel, preceding the meeting.

TRI CITY CHAPTER

On Thursday, Feb. 28, the Tri City chapter of the American Society for Steel Treating held a meeting at 8:00 p.m. at the Davenport chamber of commerce. V. A. Hain, Chicago district manager, George J. Hagan Co., presented a very interesting paper entitled, "Furnaces and Their Uses." Mr. Hain was well qualified to discuss this subject from an impartial viewpoint, because the company he represents manufactures different types of heat treating furnaces, including gas, oil, powdered coke and electric. Lantern slides were used to illustrate his presentation. Dinner was served at 7:00 p.m. preceding the meeting.

On Thursday, March 20, the chapter held a meeting at the LeClaire hotel, Moline, Ill., at which time D. M. Strickland, manager development department, American Rolling Mill Co., Middletown, O., addressed the

members on "Corrosion of Iron and Steel and Protective Coatings." Mr. Strickland gave a thorough explanation of corrosion, followed by a discussion of metallic paints, temporary coatings and protective coatings which will apply to iron and steel. He discussed each type of coating from the standpoint of its method of application and the advantages and disadvantages of the coating itself. Much interesting discussion followed this presentation. A round table discussion on the heat treatment of cast iron was lead by E. T. White. Dinner was served at 6:45 p.m. preceding the meeting.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held a meeting on Friday, March 21 at 8:00 p.m. in the auditorium of the new Interior Department building. Dr. W. M. Mitchell, metallurgical engineer, E. I. DuPont de Nemours & Co., Wilmington, Del., gave a very interesting illustrated paper entitled, "Chromium in Industry." Dr. Mitchell discussed the use of chromium in steel manufacture and its importance in the dye, paint and leather industries. He also spoke of the properties conferred by chromium on alloy, structural and tool steels, electrical and heat resisting alloys, and so-called anticorrosive or stainless metals. This meeting was very well attended.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held their February meeting in the cafeteria of the Morgan Construction Co. F. P. Gilligan, Henry Souther Engineering Co., gave a very interesting paper on "Metallography," which was illustrated with lantern slides. Mr. Gilligan showed how the microscope reveals the structure of metals and indicates the treatment which the metal has received. He also told of the value of hot acid etching in showing structural defects. This meeting was very well attended.

The March meeting of the chapter was held on the twentieth of the month, at the Morgan Construction Co. at which time L. A. Lanning, New Departure Manufacturing Co. spoke on "Quality Heat Treatment as Carried out in the Ball Bearing Industry," which was illustrated with lantern slides. Lunch was served at 6:45 p.m. in the cafeteria of the Morgan Construction Co.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ADAMS AND DURKEE STEEL CO. (S-3), 287 Atlantic avenue, Boston.

BAILEY, W. A. (M-2), superintendent, Bay State Saw & Tool Mfg. Co., *mail* Lake street, Winchester, Mass.

BAIN, E. C. (M-3), research metallurgist, Atlas Steel Corp., Dunkirk, N. Y.

BEMENT MILES WORKS (S-4), Twenty-first and Callowhill streets, Philadelphia.

BULL, R. I. (M-3), foreman of annealing room, A. O. Smith Corp., Milwaukee, *mail* 537 Fifty-fourth avenue, West Allis, Wis.

CHANNEL, E. (M-2), tool hardening department, A. O. Smith Corp. *mail* 1121 Twenty-seventh street, Milwaukee.

COLE, H. J. (M-3), research department, International Nickel Co., Huntington, W. Va.

COLMERY, L. R. (M-3), metallurgist apprentice, National Tube Co., Ellwood City, Pa.

CRAPO, F. M. (M-3), research engineer, Indiana Steel & Wire Co., *mail* 507 Riverside avenue, Muncie, Ind.

CUROE, J. J. (M-3), engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., *mail* 741 Hill avenue, Wilkinsburg, Pa.

DOUGHERTY, J. A. (Jr-1), student, Temple university, *mail* 5022 Newhall street, Philadelphia.

DRUM, C. T. (M-3), steel treater, 127 Broadway, Taunton, Mass.

EPSTEIN, M. K. (A-1), Heat Treating Equipment & Supply Co., Hartford, Conn.

EYNON, H. B. (M-3), manager, Pure Carbon Co., Wellsville, N. Y.

FRUIN, R. E. (M-3), manager, Fruin Drop Forging Co., Chicago.

GODSIL, J. J. (M-3), chemist, Crane Company, Chicago.

GRUBB, D. H. (A-3), secretary, Pacific Scientific Co., *mail* 15 Spear street, San Francisco.

HAAS, J. (M-3), assistant superintendent, Ontario Silver Co., *mail* 211 South High street, Muncie, Ind.

HEADLEY, D. G. (M-2), chemist, Columbia Steel Corp., *mail* Box 195, Pittsburg, Cal.

HENDERSON, R. (M-3), foreman production, Ace Hardware Mfg. Co., Philadelphia.

HINEY, F. J. (M-2), salesman, Brown Wales Co., *mail* 639 Walk Hill street, Mattapan, Mass.

HODGES, WM. F. (M-3), laboratory assistant, General Electric Co., *mail* 1004 Albany street, Schenectady, N. Y.

HUNT, F. G. (A-3), Wilson-Maeulen Co., *mail* 2403 Upland place, Cincinnati.

INDUSTRIAL GAS EQUIPMENT CO. (S-4), F. I. Newton, secretary, *mail* 198 State street, New Haven, Conn.

JANE, W. T. (A-3), salesman, Bausch & Lomb Optical Co., *mail* 5 North Wabash avenue, Chicago.

KNAPP, K. M. (A-3), district manager, Cyclops Steel Co., Pittsburgh, *mail* 1224 Oregon avenue, Cleveland.

KREMPF, L. W. (Jr-3), student, University of Michigan, *mail* 727 S. State street, Ann Arbor, Mich.

KRIZ, A. (M-1), chief of laboratory, Skoda Works, Plsen 6, Czechoslovakia.

KUHLMANN, F. J. (A-3), salesman, Firth-Sterling Steel Co., *mail* 2154 Buena Vista avenue, East, Alameda, Cal.

KUHN, M. A. (S-3), president, LeMoyne Steel Co., Pittsburgh.

LUCKOWSKY, A. E. (M-2), instructor in metallurgy, Michigan Agricultural college, *mail* 344 Grove street, East Lansing, Mich.

LUND, K. G. (M-3), engineer, Westinghouse Electric & Mfg. Co., *mail* 606 Sunnyside avenue, East Pittsburgh, Pa.

LUTTRELL, A. (S-3), district manager, Columbia Tool Steel Co., Detroit.

MACINNIS, E. H. (Jr-3), Franklin Union school, *mail* 62 Glendower road, Roslindale, Mass.

MALLEY, H. W. R. (M-3), manager, Canada Foundries & Forgings Co., Welland, Ont., Can.

MASSARI, S. (Jr-3), student, Massachusetts Institute of Technology, Cambridge, *mail* 477 Commonwealth avenue, Boston.

MCBEAN, J. W. (M-3), director of shop work, Central Technical school, Toronto, Ont., Can.

MCCANCE, A. (M-11), manager director, Clyde Alloy Steel Co., *mail* Westview, Uddington, Scotland.

MCFALL, J. E. (M-2), electric steel melter, Wm. Wharton, Jr. & Co., Inc., Easton, Pa.

MCFARLIN, H. F. (M-2), steel blower, Wm. Wharton, Jr., & Co., Inc., Easton, Pa.

MILLINGTON, T. E. (M-2), Evansville Arbor Press Co., Evansville, Ind.

MONTGOMERY, S. S. (M-3), superintendent steel treating department, Washburn Co., *mail* 6517 Yale avenue, Chicago.

MORGAN, C. S. (M-3), metallurgist, Automobile Machine Co., *mail* 1841 Lampson road, Cleveland.

MUMMA, P. F. (M-3), engineer apprentice, National Tube Co., *mail* 421 Lawrence avenue, Ellwood City, Pa.

NELIUS, S. (M-3), chemist, Paige Motor Car Co., *mail* 4508 Oregon avenue, Detroit.

NICOLL, S. F. (Jr-3), student, Massachusetts Institute of Technology, Cambridge, *mail* 81 Marion street, Brookline, Mass.

NICHOLS, W. E. (M-3), foreman, Lancaster Machine & Knife Works, *mail* 38 Court street, Lancaster, N. Y.

NUSBAUM, C. (M-3), assistant professor of physics, Case School of Applied Science, Cleveland.

OSTERMAN, P. C. (M-3), vice president and superintendent, American Gas Furnace Co., *mail* 19 Stiles avenue Elizabeth, N. J.

PFEIL, WM. E. (M-3), storekeeper, Studebaker Corp., *mail* 813 South Bend avenue, South Bend, Ind.

PRATT, J. W. (Jr-3), student, Massachusetts Institute of Technology, Cambridge, *mail* 1 Bennington street, Quincy, Mass.

PRINGLE, O. L. (M-2), superintendent of metallurgical and inspection department, Pittsburgh Crucible Steel Co., Midland, Pa.

REAMS, WM. H. (M-3), machinist, Meisel Press Mfg. Co., *mail* Box 159, Boston.

RESEARCH DEPARTMENT, (M-3), Eastern Malleable Iron Co., Naugatuck, Conn.

REUTHER, E. W. (Jr-3), 711 Fourteenth avenue, Rock Island, Ill.

SAUNTER, D. A. (M-3), assistant foreman steel stores, Studebaker Corp., *mail* 632 Harrison avenue, South Bend, Ind.

SCHAAP, A. I. (M-3), treasurer in chief experimental department, Schaap Iron & Steel Corp., Brooklyn, N. Y., *mail* 147 Hillside avenue, Jamaica, L. I.

SHIH, C. J. (Jr-3), student, Massachusetts Institute of Technology, *mail* Box 151, Cambridge, Mass.

SOPER, W. E. (M-3), mill foreman, Crucible Steel Company of America, Harrison, N. J.

SOUNITZA, V. (M-3), Asneft in Baku, Room 465, 11 Broadway, New York.

SULLIVAN, J. R. (M-3), supervisor of transportation, Studebaker Corp., South Bend, Ind.

SWANSON, R. O. (S-3), secretary, Elco Tool & Screw Corp., Rockford, Ill.

TALMADGE, E. F. (A-1), salesman, Halcomb Steel Co., Cleveland.

TAYLOR, C. S. (M-3), manager by-product division, Studebaker Corp., South Bend, Ind.

UHLEIN, R. F. (A-11), salesman, Julius Uihlein & Co., 208 Elm street, Cincinnati.

VOGEL, C. M. (M-3), superintendent, Vulcan Plow Co., *mail* 807 Grand avenue, Evansville, Ind.

WAITE, C. C. (M-3), manager electric heat treating department, Snead & Co., Jersey City, N. J., *mail* 154 Clay avenue, East, Roselle Park, N. J.

WAGNER, B. (M-3), Stanley Works, New Britain, Conn.

WARD, S. E. (M-3), heat treating foreman, Gemmer Mfg. Co., Detroit.

WARD'S SONS CO., EDGAR T. (S-3), 44 Farnsworth street, Boston.

WHITEHEAD, B. (M-1), general foundry foreman, Columbia Steel Corp., *mail* 279 West Third street, Pittsburg, Cal.

WIEDEMANN, T. (S-3), president, Wiedemann Machine Co., 1815 Sedgely avenue, Philadelphia.

WINN, M. (M-3) machinist, Boston Scale & Machine Co., *mail* Box 1158, Boston.

WITHERS, C. H. (M-3), mechanical engineer, Studebaker Corp., *mail* 720 West Washington avenue, South Bend, Ind.

ZURHORST, C. (Jr-3), student, University of Pittsburgh, *mail* 1463 Greenmount avenue, Dormont, Pittsburgh.

MAIL RETURNED

CORNELL, E. E., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GILHOOLY, J. H., Tate-Jones & Co., Pittsburgh.

HUNGELMANN, A., 345 Pierce street, Gary, Ind.

ILER, G. W., 1723 Thirty-first street, Moline; Ill.

SCHEIB, W. H., Buell-Scheib-Mueller, Inc., Columbia Bank building, Pittsburgh.

SCHMALZ, D. P., 5939 Grace street, Chicago.

Items of Interest

BELLIS HEAT TREATING CO., New Haven, Conn., have recently announced the publication of their booklet, "Bellis Lavite." This is a 50-page booklet describing the various types of Lavite and their various applications and method of use in the heat treatment of all types of tools.

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deCourcy Browne, Inc., metallurgical engineers and specialists on metals and alloys, at 120 Broadway, New York City, are specializing in "refined" ferromanganese (low carbon) which is particularly desirable for the following purposes: high manganese steel; low carbon steel; high nickel steel; heat resistance metal; stainless or rustless steel; tool and special steel; monel metal; manganese bronze, etc.

This new metal is likely to be of considerable interest to metallurgists and foundrymen, and a circular on this subject will be furnished on request.

A. L. Ralston, who has become general sales manager of the Braeburn Alloy Steel Corp., Braeburn, Pa., manufacturer of high speed carbon and alloy tool steel formerly was connected with the Crucible Steel Corp. of America. His association with the latter company covered a period of 22 years. During that time he was Pittsburgh district manager, assistant general sales agent, and for the last two years, Detroit district manager.

Walter I. Crocker, Pittsburgh, has become associated with the sales forces of the Braeburn Alloy corporation.

Oscar Brewer, formerly at the Philadelphia office of Leeds and Northrup Co., has been placed in charge of the company's new Cleveland office located at 1271 Union Trust building.

Colonial Steel Co. announce the appointment of W. L. Goodrich and W. H. Rieger as special representatives for die block, shoe and trimmer steel, with offices at 437 Union Trust building, Pittsburgh.

M. K. Epstein has resumed his activities in the sale of heat treating equipment by organizing and becoming general manager of the Heat Treating Equipment and Supply Co., with offices at 983 Main street, Hartford, Conn. This company is exclusive representative for the following well known lines: Surface Combustion Co., furnaces and fuel systems; Charles Engelhard, pyrometers, automatic temperature controls, and electric gas analyzers, and Quaker Oil Products Corp., quenching and tempering oils.

T. R. Harrison, formerly associated with the pyrometry department, Bureau of Standards and more recently with the Champion Porcelain Co. of Detroit, has assumed charge of the research department of the Brown Instrument Co.

A. D. Bach has resigned from the Cleveland office of the Atlas Steel Corp., Dunkirk, N. Y., and has joined the organization of Henry Disston & Sons, Inc., Philadelphia. He will be in the steel sales department in the New England territory.

Calorizing Co., have recently announced the publication of their Calco Handbook of Recuperation, which is a loose-leaf handbook designed to help improve industrial furnace practice wherever possible. It constitutes a test book containing data, tables, charts, drawings and photographs never before published. Much of the information in this book is the result of pioneer investigation in industrial furnace application conducted over a period of several years by the engineers of the Calorizing Co. The book sells for $3.00 per copy. A strictly limited edition is available for gratuitous distribution among important executives in plants operating oil, gas or coal fired industrial furnaces. The book contains 160 pages, 8½ x 11 inches, 30 full page illustrations, 30 illustrations in the text, 63 full page charts, 11 charts in the text and 5 pages of valuable tables.

Thirteen sections are embodied in this publication containing the following main points of discussion: the reason for recuperation—charts of heat losses at various furnace temperatures; the advantages of recuperation and charts showing fuel saved by this method; types of heat salvage apparatus—waste heat boilers—regenerators—recuperators; principles of combustion by recuperation—combustion calculations; improvement of combustion by recuperation—charts showing fuel losses due to combustion with excess air with fuel oil—natural gas—bituminous gas—city gas, etc.; reduction of oxidation (sale) by recuperation; influence of recuperation upon flame temperature; theory of recuperator design and elements involved; calorizing process; construction of the Calco recuperator—thermal efficiency, etc.; instructions regarding installation and operation of recuperators; and economics of recuperation.

To take care of increasing business, the Perfection Tool Hardening Co., 1229 South State Street, Chicago, have installed two of the latest type American Gas Furnace Co.'s carburizing machines.

The Twenty-eighth Annual Convention of the American Foundrymen's association will be held in Milwaukee, the week of Oct. 13, 1924.

In selecting the convention city the Board of Directors gave consideration to the demand for a location that would be convenient for foundrymen living in the middle and far west. This will be the first convention of the association held west of Ohio since 1918, and the second since 1914.

Milwaukee is the sixth city of the United States in point of number of foundries, and ranks with the first in the extent and character of its foundry activities. It is convenient of access due to the fact that it is only a two-hour ride from Chicago which is the terminal of practically all trunk lines of the country, with hourly service over the C. & N. W., C. M. & St. P., and the North Shore electric.

As in 1918, Milwaukee's auditorium will be the center of activities. This splendid building has accommodations for exhibits, general and sectional meetings, all under one roof. The Milwaukee hotels have promised their co-operation and guarantee 2000 rooms for the members and guests.

It is proposed to hold a four-day meeting, Monday to Thursday inclusive, with the exhibits opening on the preceding Saturday, as at Cleveland last